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# EXARTICULATION OF THE LOWER EXTREMITIES FOR MALIGNANT TUMORS:

## HIP JOINT DISARTICULATION (WITH AND WITHOUT DEEP ILIAC DISSECTION) AND SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

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### PART III—SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

EXCLUSIVE OF THE present series, amputation through the sacro-iliac joint, not always complete, has been performed 132 times during the past 50 years. Seventy-five per cent of the operations were performed for neoplastic diseases. The infrequency with which this radical amputation has been employed may be ascribed both to the earlier high operative mortality rates and our meager knowledge concerning the clinical behavior of tumors. During the past quarter of a century, however, the operative mortality rate has been gradually lowered from 50 per cent to about 15 per cent. Despite this, the procedure is still resorted to with relative infrequency, something which cannot be entirely attributed to the mutilating features of the operation.

A surgical procedure, especially one of radical variety, becomes useful and increasingly employed only when its indications have been clearly established, the operative mortality rate is low and the end-results justify the deformity if there is any. The purpose of this section of the present report is to evaluate the usefulness and limitations of sacro-iliac disarticulation for malignant tumors and to *standardize* the surgical technic. This study is based on six cases of exarticulation of the lower limb through the sacro-iliac joint which were performed on the Mixed Tumor Service of the Memorial Hospital during 1944 and 1945. There were no operative deaths. The fact that the first operation of this kind was undertaken so late in the history of the Mixed Tumor Service may be explained by the many years which have been required to exploit more conservative therapeutic procedures, radiologic as well as surgical, for the treatment of malignant tumors of the soft somatic tissues before resorting to an extensive deforming operation, in addition to our present more comprehensive knowledge concerning the clinical behavior of tumors of these soft parts.

*Definition.*—The term sacro-iliac disarticulation or exarticulation of the

lower limb through the sacro-iliac joint is used to designate complete removal of the lower extremity, corresponding buttock and entire innominate bone in one stage. Other names which have been employed for this operation are interpelvi-abdominal amputation, hemipelvectomy, interiliosacropubic amputation, transiliac amputation, interinnomino-abdominal amputation, hindquarter operation and disarticulation of the innominate bone.

*Historical.*—The operation was first successfully performed by Girard[6, 7] in 1895. The principles of the surgical procedure were laid down by the English surgeon, Hogarth Pringle[8] in 1916. The technic to be described in this report is a modification of the original Pringle operation.

In 1916, Pringle reviewed the literature and reported four cases of his own. The literature was reviewed again by Judin,[9] in 1926, Gordon-Taylor,[10, 11] in 1935 and 1940, Leighton[12] and Morton,[13] in 1942, and most recently by Sugarbaker.[14] These authors reported one, eleven, three, four and six cases of their own, respectively. Approximately one-half of the previously published cases survived the operation. Thirty-five per cent of the tumor patients who survived the operation were reported to be clinically cured.

## INDICATIONS

Sacro-iliac disarticulation is indicated for primary malignant osseous and periosteal tumors of the upper femur where the growth has extended to or through the hip joint and for similar neoplasms of the innominate bone (Figs. 19 and 20).* Primary bulky malignant tumors of the soft somatic tissues of the upper thigh (involving the hip joint or extending through the obturator foramen), groin, buttock, pelvic parietes and iliac region are best treated by amputation through the sacro-iliac joint (Fig. 21).

This radical amputation occasionally has a definite place in the palliative therapy of cancer. Even in the presence of hopeless extension or distant metastasis, fungating ulcerated tumors of the soft somatic tissues of the upper thigh, groin and buttock may be removed in selected cases by sacro-iliac disarticulation and gratifying results may thus be obtained, provided the patient's general condition has not deteriorated too much (Fig. 22). Elimination of sepsis and pain, conversion of a foul-smelling, bedridden patient to comfort and partial activity can be accomplished in certain hopelessly advanced cases. When the entire lower limb and groin are the seat of an uncontrolled infected neoplastic process, like Kaposi's disease (Figs. 23 and 24), palliation may be provided by amputation through the sacro-iliac joint.

Massive osteochondromas of the innominate bone and massive plexiform neurofibromas involving the upper thigh, groin and hip joint or the buttock and pelvic parietes are best treated by exarticulation of the lower limb through the sacro-iliac joint, if the tumors contain atypical areas histologically and if

* Figures 1–16 appeared in Parts I and II published in the June, 1946 issue of the ANNALS OF SURGERY.

they cannot be adequately removed by wide local excision or some other type of conservative operation.

Possible involvement of the pelvic and abdominal viscera should always be investigated by careful physical, roentgenographic and endoscopic examinations. If necessary, preliminary celiotomy should be performed to ascertain

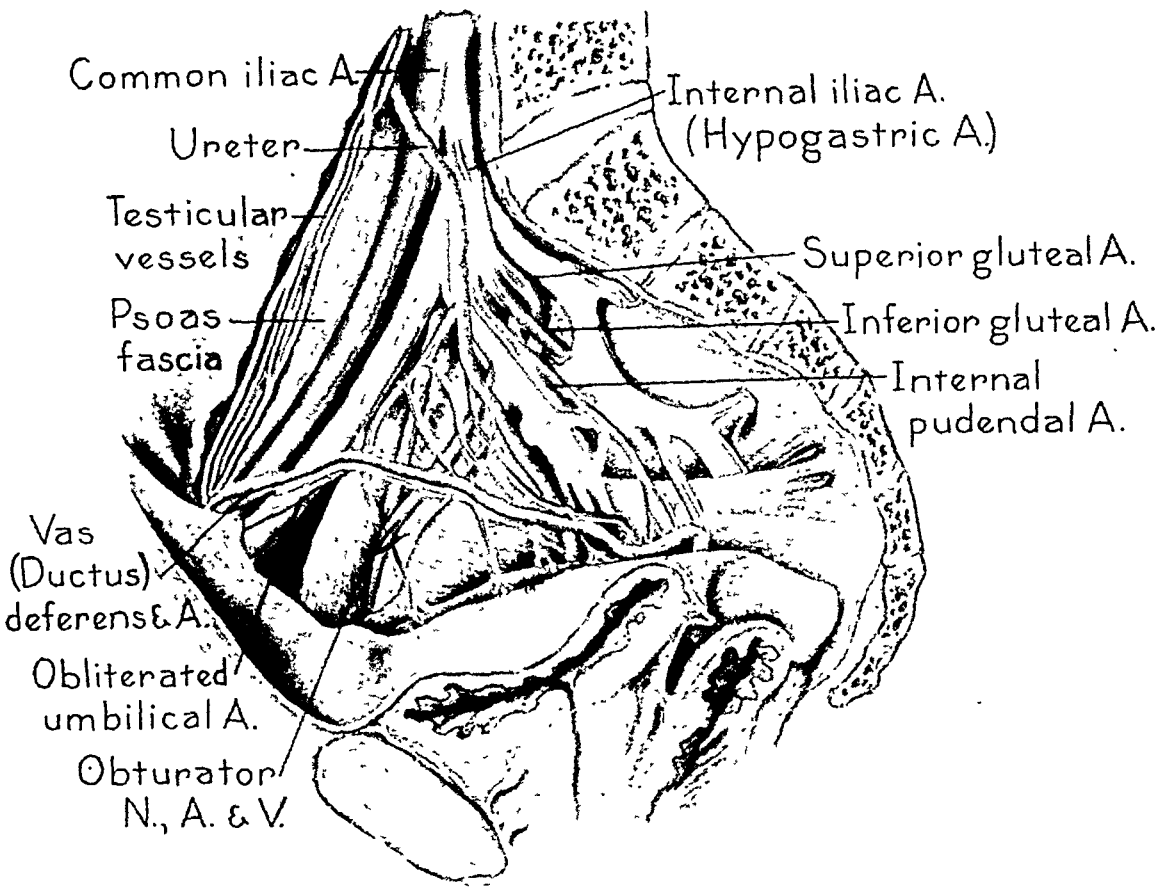



FIG. 17.—Sagittal view of pelvis and retroperitoneal space, showing the iliac vessels and their branches. (Redrawn from Grant's Atlas of Anatomy.)

the extent of the growth and possible peritoneal involvement. Wide extension of the neoplasm should not always deter the surgeon from performing the operation. Part of the sacrum was resected in one case and a testicle was removed in another in Gordon-Taylor's series.[10, 11] In Case 6* of the present series, a considerable portion of scrotal skin was included in the dissection.

The operations which are here reported were performed for Kaposi's hemorrhagic sarcoma, myxoliposarcoma, chondrosarcoma, neurogenic sarcoma, periosteal fibrosarcoma and extra-osseous osteogenic sarcoma. One operation was performed for palliative purposes only (Case 1). It is mandatory that an anatomic diagnosis be established by aspiration or incisional biopsy before radical amputation or any other surgical or nonsurgical program

* Case numbers employed in Part III of this paper refer to our series, which are individually reported elsewhere in this section.

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FIG. 18.—Roentgenogram of pelvis, showing chondrosarcoma of right pubis and ischium in Case 3. A favorable tumor for treatment by sacro-iliac disarticulation.

*Below:* Postoperative roentgenogram showing absence of affected innominate bone.

for that matter is planned. Of the cases which were previously reported by other authors, one surgical specimen contained metastatic renal carcinoma[14] and another metastatic thyroid carcinoma,[13] whereas, in both of these cases the operations were carried out specifically for a primary malignant tumor.

## PREOPERATIVE CONSIDERATIONS

The preoperative considerations and precautions which were discussed for hip joint disarticulation are also applicable for cases of sacro-iliac disarticula-

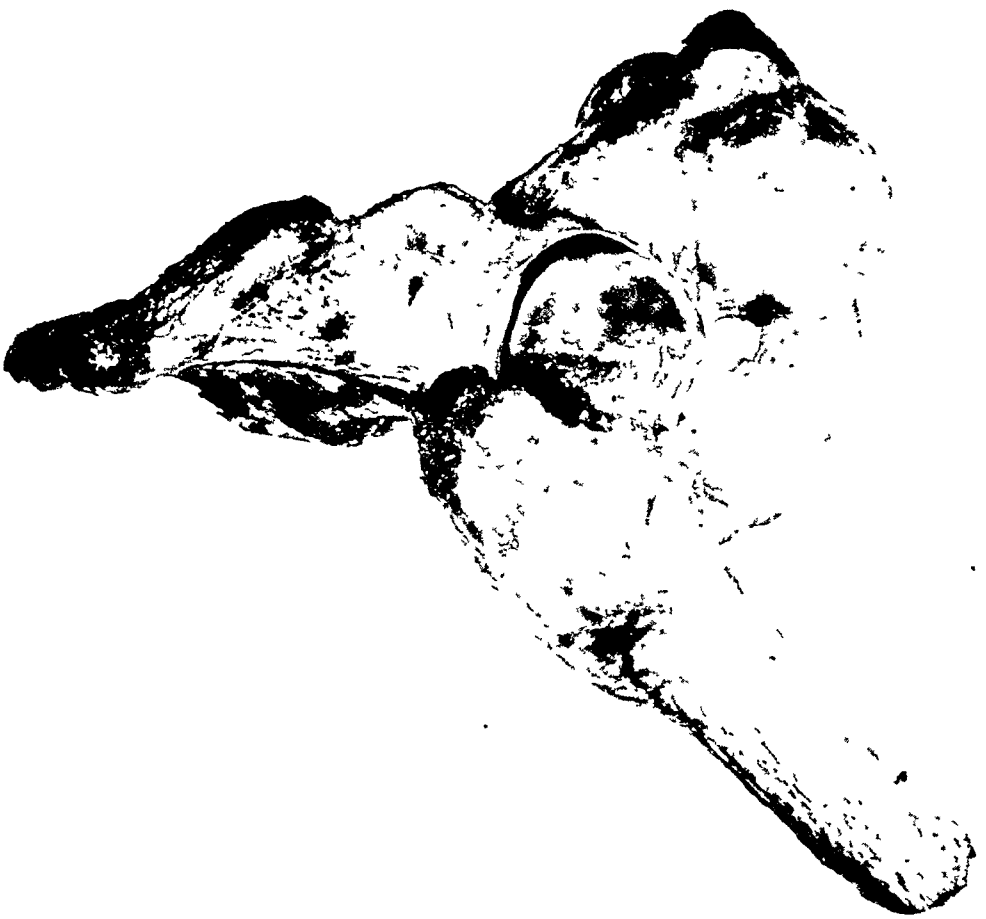


FIG. 19.—Surgical specimen in Case 3. Almost complete replacement of pubis and ischium by tumor.

tion. Douches and surgical cleansing of the vagina, daily antiseptic sprays and dressings, débridement for ulcerated, infected and necrotic tumors, blood transfusions for anemic and toxic patients, eradication of urinary tract infections and adequate correction of hypoproteinemia and other metabolic factors, if present, are essential features in preparing the patient for this radical operation. If the neoplasm is fungating extensively, much of the fungating portion may be excised with the cautery several days before amputation is performed (Case 6). In this way the operative field can be more thoroughly prepared. The application of an elastic bandage to the affected limb (except in cases of melanoma) and preoperative cleansing of the

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FIG. 20.—Surgical specimen in Case 5. Periosteal fibrosarcoma involving ischium, hip joint and greater trochanter. A malignant tumor so located can only be completely removed by sacro-iliac disarticulation.

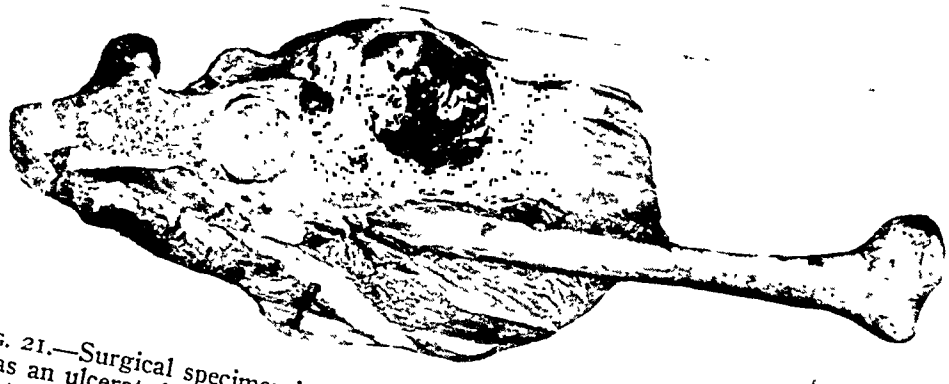


FIG. 21.—Surgical specimen in Case 6. Extra-osseous osteogenic sarcoma which presented as an ulcerated tumor in the groin and involved part of the scrotal skin. Treated by repeated cycles of roentgenotherapy elsewhere, with no regression, before admission to Memorial Hospital for sacro-iliac disarticulation. Note proximity of neoplasm to pubic bone and capsule of hip joint.

bowel with colonic irrigations are highly desirable. A Foley urethral catheter is inserted into the bladder before the patient is taken to the operating room.

Inhalation anesthesia is the anesthetic of choice for reasons given in Part I of this report. A blood transfusion is begun as soon as the operation is started and an adequate amount of compatible blood should be on hand in the operating room.

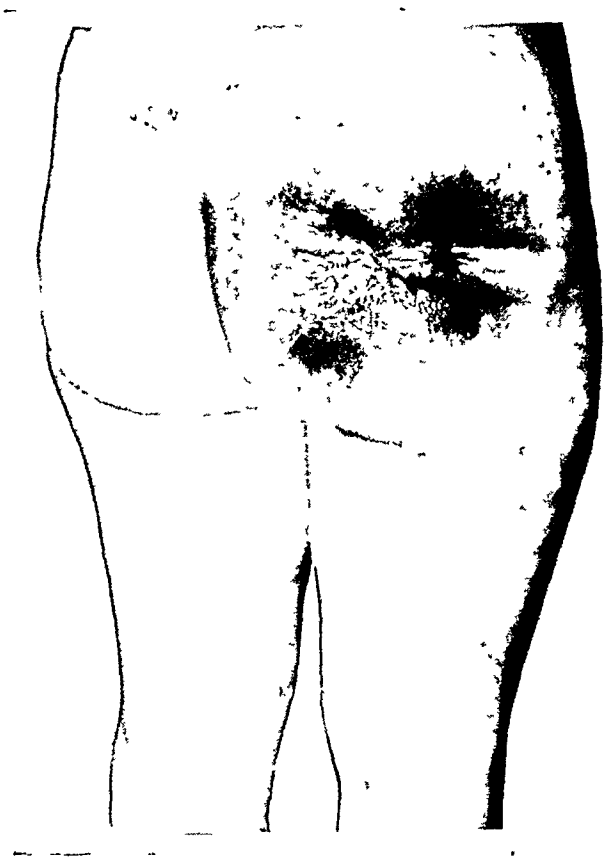


FIG. 22.—Case 2: Extensive myxoliposarcoma of buttock. Neoplasm deeply infiltrated gluteal muscles and sacral foramina. Sacro-iliac disarticulation was performed to relieve intense intractable pain. Tumor could not be controlled with radiation therapy.

## OPERATIVE TECHNIC

After the operative area has been cleansed and prepared, the anal opening is closed with a purse-string suture and, in the male, the scrotum is sutured to the opposite thigh. The skin of the entire field is again painted and the patient is draped.

An incision is made from a point just above the pubic tubercle, extending upward and outward, to a point just beyond the iliac crest. This incision corresponds to the curve of the inguinal ligament and the iliac crest. The posterior flap is outlined by carrying the lateral termination of the anterior incision downward coursing above the greater trochanter and along the infragluteal groove to the perineum. It is then joined with the medial end of the anterior incision at the superior border of the symphysis pubis (Fig. 25).

The anterior incision is deepened through subcutaneous tissues and fascia in its entirety. The rectus abdominis is divided at its insertion into the pubic bone. The inguinal ligament is severed at its lateral attachment to the anterior superior iliac spine and its medial attachment to the pubis. In this way the anterior abdominal wall is actually detached from the bony pelvis, forming the anterior flap. (Fig. 29). The spermatic cord is preserved and retracted.

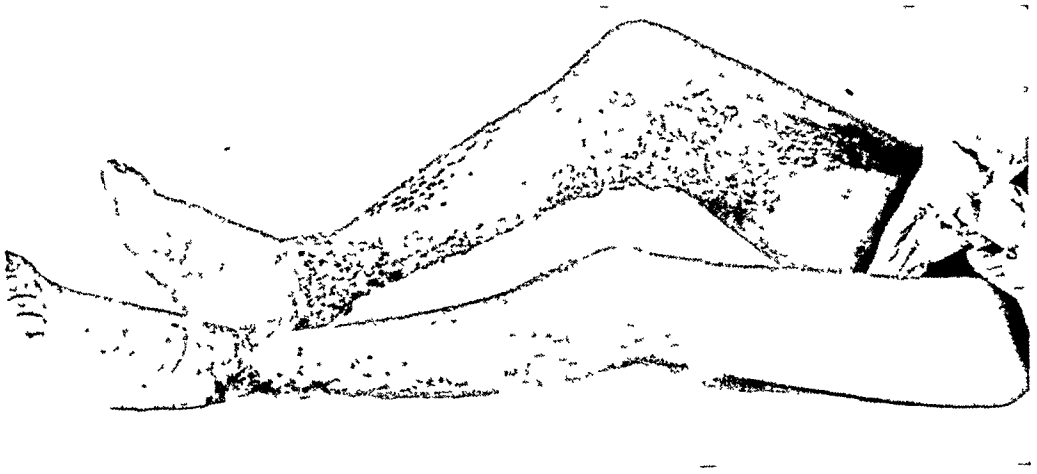


FIG 23.—Case 1. Kaposi's hemorrhagic sarcoma in a 16-year-old boy. Entire right lower limb and groin were ulcerated, infected and deeply invaded by tumor. Only the lesions on the left leg could be satisfactorily controlled with roentgenotherapy. Palliative amputation through the sacro-iliac joint restored a septic, foul-smelling, bedridden patient to comfort and partial activity.

The peritoneum is stripped off and the abdominal contents are pushed upward and medially; the urinary bladder is pushed downward and medially. The iliac fossa and its contents are thus exposed. Three structures—peritoneum, intestines and bladder—must be constantly retracted during the anterior dissection. The ureter must also be identified. The external iliac artery is doubly ligated and divided (Fig. 30). The external iliac vein is not ligated at this time to allow for a maximum return of blood from the limb The pubic symphysis is exposed, skeletonized and easily divided with a Gigli saw or chisel (Fig. 31). The symphysis must be clearly identified, otherwise the corresponding or contralateral pubic arch will instead be transected. Considerable bleeding not infrequently follows separation of the symphysis pubis, due to cutting of vascular erectile tissue (ischiocavernosus). Hemorrhage is promptly controlled by packing.

The posterior skin flap is developed as far back as the sacrum (Fig. 32).

The anterior dissection is continued. The crest of the ilium is skeletonized, including severance of the attachment of the quadratus lumborum muscle. The external iliac vein is now doubly ligated and divided but the internal iliac vein is preserved. The iliopsoas muscle is then transected as high as possible. The iliacus, pyriformis, gamelli and levator ani muscles are divided and the sacro-iliac joint is exposed (Fig. 33).

Disarticulation of this joint is performed during the anterior phase of the

dissection, using a chisel. The bevel of the chisel and the direction of the instrument must be *away from the midline*. Injury to the hypogastric vein must especially be avoided at this time. The sacro-iliac synchondrosis is divided with relative ease. If difficulty is encountered, it is most probable that the ilium down through the sacrosciatic notch is being cut through rather than the synchondrosis. Troublesome bleeding which occasionally follows division of the sacro-iliac joint is controlled by packing and pressure.

The patient is turned on the unaffected side and the posterior dissection is carried out. The posterior attachments of the gluteal muscles are divided (Fig. 34). The limb is then sharply flexed and adducted. The specimen is now attached to the patient only by the major ligaments of the sacrum and the great nerve trunks. The ligaments are divided from below upward and the gluteal and obturator arteries are caught, cut and ligated. The specimen is removed (Fig. 35-A).

The large nerve trunks of the lumbar and sacral plexus are injected with alcohol and ligated. Absolute hemostasis is obtained. Sharp bony projections, if present, are eliminated. Redundant skin and muscle tags are trimmed and the wound is thoroughly irrigated with saline solution. The flaps are approximated with interrupted stitches after two cigarette drains have been placed in the defect and allowed to emerge through the ends of the wound (Fig. 35-B). The temporary scrotal and anal sutures are removed and a bulky pressure dressing is applied.

*Anterior Dissection.*—With this technic, all of the major phases of the operation are performed through an anterior approach except for division of the sacral ligaments, lumbar nerve trunks and gluteal and obturator arteries. The contents of the iliac fossa are easily exposed and the peritoneum, intestines and bladder can be retracted well out of the way, protecting them from possible injury. Both synchondroses may also be adequately exposed, cleared and divided under direct vision with little difficulty by approaching them anteriorly. Furthermore, it will not be necessary to turn the patient, occasionally in shock, too often in order to expose the necessary anatomic structures. The patient is turned only on three occasions—once for outlining the posterior incision, again, for development of the posterior flap, and a third time, when the posterior dissection or final phase of the amputation is performed.

*Ligation of the Common Iliac Artery.*—Amputation through the sacro-iliac joint may be performed in a relatively bloodless manner if the common rather than the external iliac artery is ligated. In this way there is no vigorous bleeding when the parietal branches of the hypogastric artery are cut and the amount of bleeding which follows division of the pubic and sacro-iliac synchondroses is amazingly small. Ligation of the common iliac artery, however, has its drawbacks and should not be done routinely. In Case 5 of the series here reported, the common iliac artery was ligated and the above observations with regard to hemostasis were made. At no time did the pulse or blood pressure change in any way. When the specimen was removed, the posterior flap appeared viable. On the fourth postoperative day there was some necrosis

along the suture line and two relatively small areas of necrosis appeared in the skin of the posterior flap. At this time, the wound began to drain large amounts of thick brown pus. On the seventh postoperative day the two eschars were excised and it was found that the middle third of the anterior half of the posterior flap was completely necrotic. Necrosis of the posterior flap following ligation of the common iliac artery for sacro-iliac disarticulation has also been observed by others.*

Ligation of the common iliac artery may be rarely indicated in poor risk patients where excessive bleeding, shock and a prolonged operation are to be avoided at all costs. Under such circumstances it might be preferable to risk possible necrosis of the posterior flap with its sequelae rather than an operative death. In such a case it would be advisable to develop an extremely thin posterior skin flap, making certain that it has been completely denuded of subcutaneous fat, for the blood supply which is destroyed by ligation of the common iliac artery essentially feeds into the subcutaneous fatty tissues and not into the overlying skin. In this way, the posterior flap becomes a full-thickness skin graft; if it is snugly and uniformly held against the underlying tissue bed by a judiciously applied pressure dressing, gangrene of the posterior flap and secondary infection might thus be avoided. The phenomenon of delayed or latent necrosis of the posterior flap which occurs after ligation of the common iliac artery for amputation through the sacro-iliac joint is actually secondary involvement of the skin by a gangrenous process which originates in the subcutaneous fat soon after the parietal branches of the hypogastric artery can no longer maintain an adequate circulation. It is only after spread of the necrotic process to the skin itself, which apparently takes a few days, that the necrosis can be seen externally, and by that time the wound is extensively infected.

*Critical Period of the Operation.*—The critical period of the operation is during partition of the sacro-iliac synchondrosis at which time shock occasionally occurs. Since the posterior dissection with subsequent division of the gluteal and obturator arteries immediately follows as the next step in the operation, it is essential that the blood pressure be maintained within reasonably normal limits before the posterior dissection is begun because it is during this last phase of the procedure that further appreciable hemorrhage might be encountered. Accordingly, we routinely start a second blood transfusion in the contralateral foot as a precautionary measure just prior to disarticulation of the sacro-iliac joint, so that the patient is not in shock at the time the specimen is removed.

*Skin Grafting.*—In the event that a considerable portion of the anterior or posterior abdominal walls must be included in the amputation because of involvement by tumor or radiation injury, the skin flaps might not be adequate

* A seventh hemiplevectomy has just been performed, with no postoperative complications. In this instance the common iliac artery was ligated early in the course of the operation. The wound healed *per primam*, with no evidence of ischemia and no infection. The patient was a 39-year-old man who had an enormous myxoliposarcoma of low-grade malignancy involving the left upper thigh anteriorly and extending superiorly to the groin and over the anterior superior iliac spine.

for primary wound closure. Under such circumstances sufficient skin may be readily removed *from the amputated specimen* with the dermatome to cover the defect.

## POSTOPERATIVE COMPLICATIONS

Aside from the distressing pains of phantom limb, a satisfactory postoperative course may be expected provided the proper prophylactic measures to prevent complications specific for cases of sacro-iliac disarticulation are instituted.

*Abdominal Distention.*—This is practically a constant and occasionally disturbing postsurgical complication. The etiology is obscure. Retraction and manipulation of the peritoneal contents for approximately three hours during the operation probably is not responsible for this complication. Division of the large nerve trunks of the lumbar and sacral plexus might conceivably depress the celiac and superior and inferior mesenteric sympathetic plexuses and, thus, account for the ileus. If a Levine tube is placed in the stomach as soon as the patient has fully reacted from the anesthetic and constant Wangensteen suction is continued for 48 to 72 hours, serious abdominal distention can be avoided. During this period fluid and electrolyte imbalance must be corrected and hypoproteinemia, a not uncommon complication, combatted by administration of large amounts of plasma.

*Paresis of the Urinary Bladder.*—Inability to void, due to paresis of the bladder, occurs often but is only temporary, lasting four to seven days. A Foley urethral catheter should be placed in the bladder before the patient is taken to the operating room. Thus, the bladder is kept empty during the operation and is less likely to be injured. When the patient is returned to his bed, urinary tidal drainage is established and maintained for about one week. Not only is this method of catheter drainage beneficial to the atonic bladder but it also prevents soiling of the dressing during the first postoperative week. When the catheter is finally removed, patients void spontaneously. No instance of postsurgical urinary tract infections were encountered.

*Wound Healing.*—Continued and often profuse drainage for a period of about three weeks is almost a constant feature following sacro-iliac disarticulation. This may be attributed to necrosis of muscle tags, lymphorrhea and liquefaction of fat. Necrosis of skin flaps will occur if the blood supply is inadequate or if the tissues have been devitalized by roentgenotherapy. In Case 5 of this series the common iliac artery was ligated and the posterior flap underwent extensive latent necrosis. In Case 6, healing was unsatisfactory due to previous radiation therapy to the operative site, and pinch-grafts were required to cover the resultant defect. If the tumor has been previously heavily irradiated, every effort should be made to excise all of the radiated skin, otherwise delayed or nonhealing is inevitable.

Frank wound infections were commonly encountered despite exhaustive preoperative prophylactic measures, which were discussed elsewhere in this report, and adequate postoperative chemotherapy. The proximity of the oper-

ative area to the anus and genitals, the ulcerated, necrotic and extensively infected state of many of the neoplasms, postoperative anemia and hypoproteinemia, together with a frequent history of heavy irradiation to the tumor, were the factors which contributed to the high incidence of postsurgical wound infections. There were no instances of vesical, enteric or ureteral fistula or permanent sinus formation in our cases or in any of the previously reported cases where the operation was performed for neoplastic disease.

Osteomyelitis was encountered in one instance (Case 6). At this operation the contralateral pubic arch was divided, instead of the pubic symphysis, thus exposing cancellous bone. Since the tumor had been extensively infected and previously heavily irradiated, this complication was inevitable.

*Anemia.*—This is a characteristic postoperative manifestation following sacro-iliac disarticulation but does not consistently appear after hip joint, interscapulothoracic or any other type of amputation. Naturally, patients who require sacro-iliac disarticulation are not infrequently anemic because of sepsis, radiation therapy or malnutrition due to pain. In these cases the blood picture is brought to within reasonably normal limits by appropriate preoperative measures. Some of the patients may lose considerable blood during the operation. This loss, however, is adequately replaced by blood transfusions. In those cases where the blood loss is 500 cc., or less, anemia still appears during the immediate postsurgical period. In Case 5 of the present series the common iliac artery was ligated and the blood loss was negligible; this patient, too, developed an anemia. It also occurs when massive blood transfusions are not given during the operation and, therefore, cannot be attributed to excessive destruction of red cells in the spleen, with subsequent bone marrow depression. The anemia can neither be ascribed to blood loss during operation or to any specific systemic preoperative factors. It is not unlikely, therefore, that removal of an entire lower extremity and innominate bone deprives the hemopoietic system of sufficient active bone marrow, thus producing anemia. This normocytic normochromic anemia is noted during the first few postoperative days and persists for about three weeks. It does not respond to blood transfusions, liver or iron therapy. An increase of reticulocytes in the peripheral blood and of nucleated red cells in the sternal marrow were also noted postoperatively, indicative of compensatory marrow hyperplasia.

*Function of Anal Sphincter.*—Fecal incontinence or other disturbances of sphincteric control do not occur following sacro-iliac disarticulation despite complete division of the levator ani muscle on the affected side. This may be attributed to the cross-insertion of these muscles so that preservation of the sphincter and an intact contralateral levator ani muscle are wholly adequate for satisfactory sphincter control.

*Hernia.*—The abdominal contents are merely supported by skin, subcutaneous tissue, fascia and peritoneum, yet there has been no instance of herniation. There is no need, therefore, for preserving the gluteus maximus muscle since it does not materially make for a better stump. No device for supporting the abdominal wall is necessary, although one has been introduced.[15]

*Prosthesis.*—A prosthesis has never been devised for these cases. The patients learn to sit on the opposite ischial tuberosity. They manage to use crutches satisfactorily after about three weeks of practice. Despite the mutilating features of this radical amputation the psychologic adjustment parallels that following ordinary amputation, except that loss of libido occurs rather frequently.

## CASE REPORTS

**Case 1.**—*Sacro-iliac Disarticulation for Kaposi's Hemorrhagic Sarcoma of the Lower Extremity:*

A. G., a white male, age 16, was first seen at the Memorial Hospital, September 29, 1944, for Kaposi's hemorrhagic sarcoma involving the lower limbs. Bluish nodules in the skin of the right leg were noted in 1938. In 1941, the patient was subjected to a bilateral saphenous vein ligation for varicosities. Shortly after, the tumors on both lower limbs were treated with roentgen ray. On admission, the patient was profoundly anemic, bedridden and suffering from sepsis. There were literally thousands of tumor nodules which involved both lower extremities (Fig. 23). The lesions on the left leg had been satisfactorily controlled with previous radiation therapy. The tissues of the right lower limb were edematous and infiltrated by tumor up to and including the femoral trigone. The odor was extremely foul. Radiographic studies of the chest and bony pelvis revealed no evidence of metastasis.

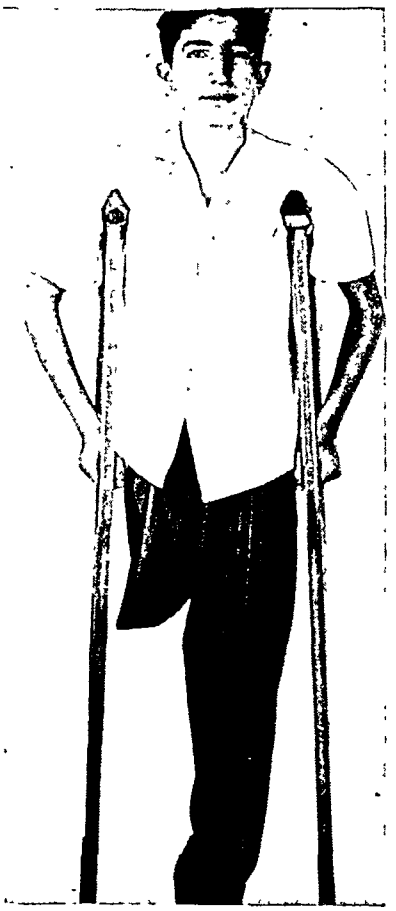


FIG. 24. — Postoperative photograph in Case 1.

The infection could not be controlled by local care or chemotherapy, and the pain was intense. Radical amputation for palliation was, therefore, decided upon. Hip joint disarticulation could not be undertaken because considerable tumor would be left behind Accordingly, a right sacro-iliac disarticulation was performed on November 8, 1944. Since the skin of the entire limb had been replaced by infected fungating tumor reaching to the level of the greater trochanter, a considerable portion of skin had to be sacrificed. This was accomplished by placing the anterior racquet incision at a point midway between the umbilicus and anterior superior iliac spine. Otherwise the usual technic for amputation through the sacro-iliac joint was carried out. The patient received two liters of blood during the operation and one and one-half liters during the first five postoperative days.

The wound healed satisfactorily except for moderate serous drainage for a period of three weeks. The only complications of note were abdominal distention and anemia. At no time was there any fecal incontinence. After four days of continued catheter drainage the patient was able to void spontaneously. He was discharged on the 25th postoperative day. Follow-up examinations have revealed several recurrent nodules in the skin of the right lower anterior abdominal wall which responded satisfactorily to low-voltage roentgenotherapy.

*Pathology.*—Almost the total area of the skin surface of the exarticulated hindquarter was involved by multiple and conglomerate, infected, foul-smelling, grayish-brown nodules. There was considerable thickening of the skin. The lesions were scattered from the toes to the upper thigh. The entire extremity was greatly swollen. On sectioning, the subcutaneous tissues and muscle were found to be deeply invaded by tumor. Numer-

ous large masses were encountered in the inguinal and iliac regions. The line of amputation lay well above the uppermost recognizable lesion. Microscopic study revealed the usual structure of Kaposi's hemorrhagic sarcoma. The nodules in the inguinal and iliac regions proved to be discrete tumors adjacent to but not involving the lymph nodes.

*Comment.*—This procedure was purely palliative for an hopelessly advanced infected tumor which had completely disabled the patient. The operation succeeded in removing an offensive tumor-ridden limb so that the patient regained a reasonable measure of health and is again ambulatory (Fig. 24).

Case 2.—*Sacro-iliac Disarticulation for Myxoliposarcoma of the Buttock.*

M. M., a 57-year-old white female, was first seen at the Memorial Hospital, July 31, 1944, for a tumor of the right buttock of 15 years' duration. The previous history was essentially normal. The neoplasm had been excised 11 and nine years ago, respectively; two subsequent recurrences were treated with roentgenotherapy. For one month prior to admission the patient had severe intractable pain in the right buttock and pelvis. This buttock was the seat of a reddened, indurated, infiltrating tumor, measuring about 6 cm. in greatest diameter (Fig. 22). The central portion of the mass was necrotic and ulcerated. Several discrete nodules were palpable in the right iliac region. Radiographic studies of the chest, spine and bony pelvis revealed no evidence of metastasis. A biopsy was reported myxoliposarcoma.

After two weeks of preparation, which included local cleansing, penicillin therapy and blood transfusions, a right sacro-iliac disarticulation was performed in the usual manner. During the operation it was noted that the tumor extended deep to the underlying muscles, replacing two-thirds of the buttock. It was densely adherent to the adjacent ilium and also extended through several sacral foramina. The patient received two liters of blood during the procedure.

Convalescence was complicated by the development of a phlebothrombosis in the opposite leg which was treated by femoral vein ligation. At no time was there any fecal incontinence. After four days of continuous catheter drainage the patient was able to void spontaneously. Abdominal distention was a prominent feature during the first postsurgical week and was treated by an indwelling gastric tube and Wangensteen suction. An additional liter of blood was administered during the first postoperative week for anemia, which persisted despite this treatment. The patient was discharged on the 23rd postoperative day with some slight serous discharge from the wound.

On May 23, 1945 severe pain developed in the upper part of the stump. Examination revealed a tender mass in the right iliac area. Roentgenogram of the chest showed no evidence of lung metastasis. The patient was readmitted to the hospital for a course of high-voltage roentgenotherapy, after which there was marked regression of the mass and complete amelioration of symptoms. Several days after the completion of roentgenotherapy, flaccid paralysis of the remaining lower extremity developed together with loss of urinary bladder control. Neurologic examination disclosed evidence of cord block at D 7 to D 9. Radiographic studies of the spine revealed no evidence of bony involvement. Lumbar puncture yielded clear straw-colored fluid under an initial pressure of 95 mm. of water; the final pressure was 20 mm. The spinal fluid protein determination was 1,110 mg. per 100 cc. of spinal fluid. Urinary tidal drainage was established and the involved thoracic spinal segment was outlined for roentgenotherapy.

On June 27, 1945 the patient developed chills and fever up to 105° F. She continued very septic, and expired, July 2, 1945, approximately one year after amputation. Permission for an autopsy was not obtained.

*Pathology.*—The right buttock contained a deep, dirty, foul-smelling, ulcerated tumor, measuring 8 cm. in greatest diameter. The tumor was soft, gelatinous and partly cystic. It extended through the gluteus maximus muscle and soft tissues adjacent to the greater sciatic notch. There was no actual infiltration of bone. It was reasonably certain from gross examination that the neoplasm had not been completely excised. Microscopic study revealed the usual histologic features of myxoliposarcoma.

*Comment.*—This is another instance of amputation through the sacro-iliac joint for palliative purposes only. A cure could not be anticipated in this case because the tumor had extended through the sacral foramina, with the expectancy that the spinal cord would eventually become involved. The operation succeeded in removing a necrotic, infected, foul-smelling hindquarter which was the source of intense intractable pain and which made the patient offensive to others. The tumor could not have been controlled by roentgenotherapy.

**Case No. 3.**—*Sacro-iliac Disarticulation for Chondrosarcoma of Pubis and Ischium.* J. M., a 60-year-old white male, was first seen at the Memorial Hospital, January 18, 1945 for a mass in the right groin of six months' duration. The tumor produced considerable pain especially on walking. There had been no apparent increase in its size since it was first noted. Examination revealed a definite mass in the right parapubic area. Radiographic studies showed evidence of a multicystic, expansile, osteolytic process involving the right pubis and ischium (Fig. 18). It did not appear to extend into the ilium or acetabulum. Roentgenograms of the chest and remaining skeleton revealed no evidence of this disease process. Aspiration biopsy yielded no characteristic tissue.

An exploratory operation was carried out January 19, 1945. Tissue was submitted to the Pathologic Laboratory for immediate examination and a diagnosis of chondrosarcoma was made. A right sacro-iliac disarticulation was then performed in the usual manner. Because of the size of the tumor, it was necessary to expose the posterior urethra and prostate gland. The patient received one liter of blood during the procedure and one liter during the first four postoperative days.

There was no fecal incontinence. The patient was able to void spontaneously after seven days of tidal bladder drainage. During the first postsurgical week the convalescence was complicated by marked ileus, which was treated with continuous Wangensteen gastric suction and daily colonic irrigations. The wound healed satisfactorily and ceased to drain during the third postoperative week. A normal blood count was also obtained at this time. The patient was discharged on the 28th postoperative day.

*Pathology.*—The specimen consisted of an entire lower extremity, buttock and corresponding innominate bone. Examination of the major vessels revealed no evidence of intravascular tumor extension. There were no grossly involved lymph nodes. After the soft tissues and muscles were dissected from the innominate bone, a large mass was seen to occupy the pubic bone (Fig. 19). The tumor was covered by a relatively thick capsule which apparently was the fascial covering of the neighboring muscles. The neoplasm was composed of grayish, cartilaginous-like tissue intermingled with opaque grayish areas. It extended through the obturator foramen. On section of the innominate bone, the growth was seen to involve most of its pubic portion. It also extended for a short distance into the proximal ilium and distal portion of the ischium. The articular capsule of the acetabulum in the region of the pubis was also involved. The cortex of the bone was intact everywhere except for the ramus of the pubis. The neoplasm entirely replaced the marrow of the involved portion of bone. Abundant new periosteal bone formation was seen at the junction of pubis and proximal ilium. In its over-all dimensions the tumor measured 8 x 8 x 7 cm. Microscopic study revealed the usual structure of chondrosarcoma.

*Comment.*—Sacro-iliac disarticulation was necessary in order to excise a bulky malignant tumor which almost replaced half of the bony pelvis. The growth was surgically accessible. The prognosis following amputation through the sacro-iliac joint is best in this type of case.

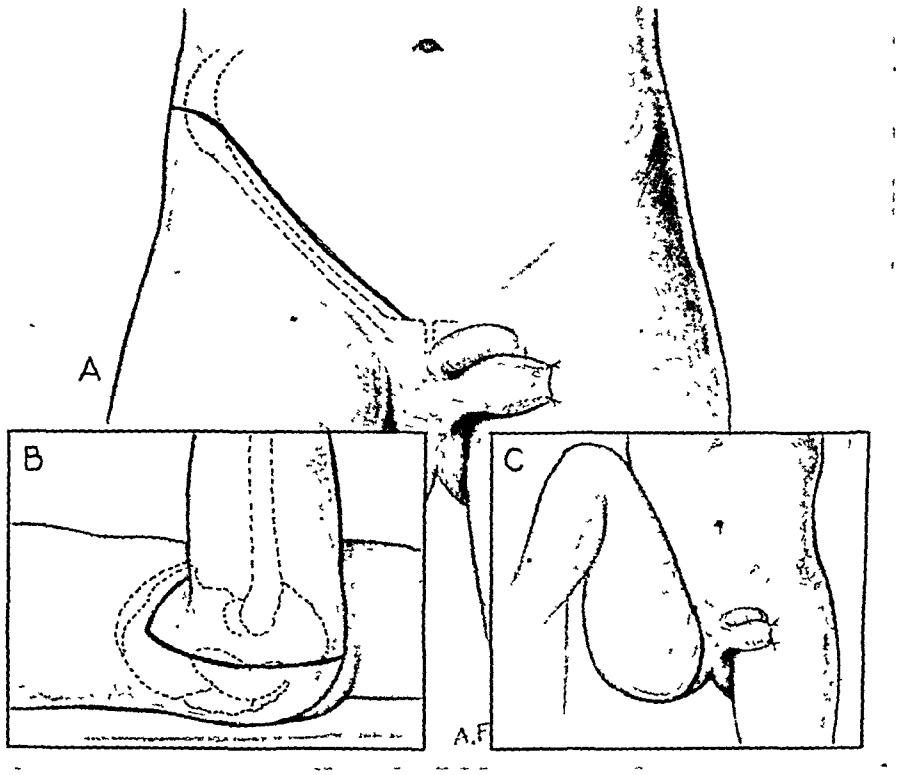



FIG. 25.—Incision for sacro-iliac disarticulation.

(A) The anterior incision extends from the pubic tubercle to beyond the iliac crest, paralleling the inguinal ligament.

(B) The posterior flap is outlined by carrying the lateral termination of the anterior incision downward, coursing above the greater trochanter and along the infragluteal fold to the perineum.

(C) The anterior and posterior incisions are then joined at the superior border of the symphysis pubis.

**Case No. 4.**—*Sacro-iliac Disarticulation for Neurogenic Sarcoma of the Thigh and Pelvic Parietes.*

L. R., a 15-year-old white female, was first seen at the Memorial Hospital, November 19, 1936, for von Recklinghausen's neurofibromatosis. No familial history of this disease could be elicited. In 1935, the patient sustained an injury to the left buttock, which was followed by considerable pain and swelling. The pain subsided after two weeks but the swelling persisted and slowly increased in size.

The child was undersized. Diffuse circumoral pigmentation was present. Numerous café-au-lait spots were distributed over the trunk and limbs but no discrete superficial neurofibromas were palpable. Situated on the posterior aspect of the upper left thigh just beneath the gluteal fold was an oblong tumor, measuring 13 x 10 x 10 cm. (Fig. 26). The mass was movable and not adherent to bone or skin. Roentgenograms of chest and left

femur showed no evidence of metastasis or bone involvement. The liver was not palpable. Aspiration biopsy yielded no characteristic tissue for diagnosis. A clinical diagnosis of neurogenic sarcoma of the left sciatic nerve was made.

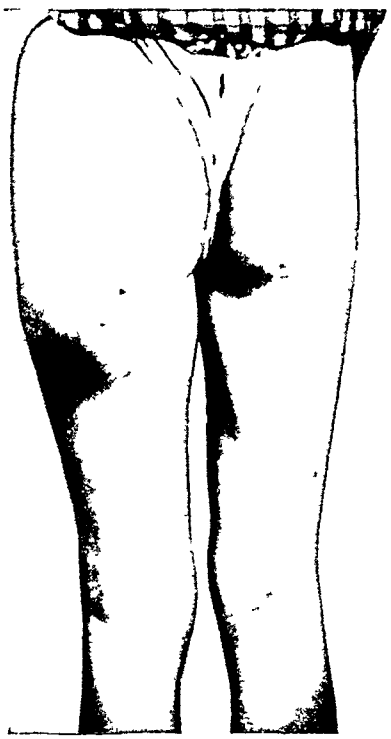


FIG. 26.—Case 4: Von Recklinghausen's neurofibromatosis. Plexiform neurofibroma on posterior aspect of left thigh (not associated with sciatic nerve). Excised in 1936. Note *café-au-lait* spots, which are frequently present in this disease.

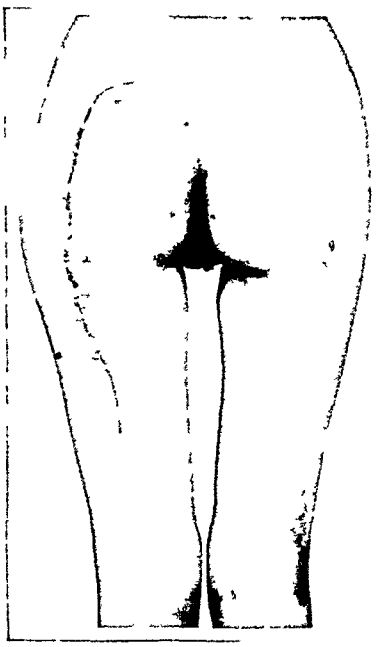


FIG. 27.—Case 4: Seven years later. Fully-developed neurogenic sarcoma originating in sciatic nerve. Tumor extended through obturator foramen to involve pelvic parietes. This extension was first determined by exploratory operation through the thigh and buttock. A favorable case for amputation through the sacro-iliac joint.

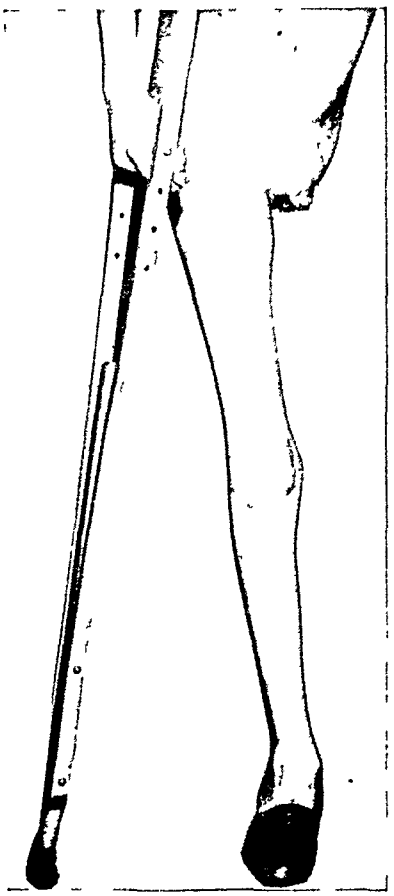


FIG. 28. — Postoperative photograph in Case 4.

On December 9, 1936, wide local excision of the mass was done. An encapsulated, edematous, partly cystic tumor, measuring 8 cm. in longest diameter, was found beneath the short head of the biceps femoris muscle. The neoplasm was attached to a medium-sized branch of the sciatic nerve and extended down to but did not involve the periosteum of the femur. It also extended along the sciatic nerve downward to the popliteal space and upward to the obturator foramen. Numerous nodular, firm, encapsulated masses were present all along the sciatic nerve—characteristic of this disease. The large neoplasm was easily excised but no attempt was made to enucleate the myriads of neuromas which involved all median and large nerve trunks. The sciatic nerve was left intact. Microscopic examination of the excised tumor revealed the typical structure of plexiform neurofibroma, lacking any of the true features of malignant transformation.

The patient was examined at periodic intervals for the next seven years and on February 26, 1945 a mass, measuring 10 x 6 cm., was noted beneath the upper end of the scar (Fig. 27): Aspiration biopsy was done and a diagnosis of neurogenic sarcoma was established. An attempt at wide local excision was carried out on March 30, 1945. The neoplasm actually replaced a greater portion of the main sciatic nerve and perforated the obturator foramen to involve the pelvic parietes. Removal of the tumor through this approach was impossible. The wound was closed. Sacro-iliac disarticulation was advised but consent was not granted until three months later.

On June 15, 1945, a left sacro-iliac disarticulation was performed in the usual manner. During the operation it was noted that all major nerve trunks contained numerous neuromas. The patient received two liters of blood during the procedure. Although studies for estimation of blood loss were not carried out, it was considered less than average in this case.

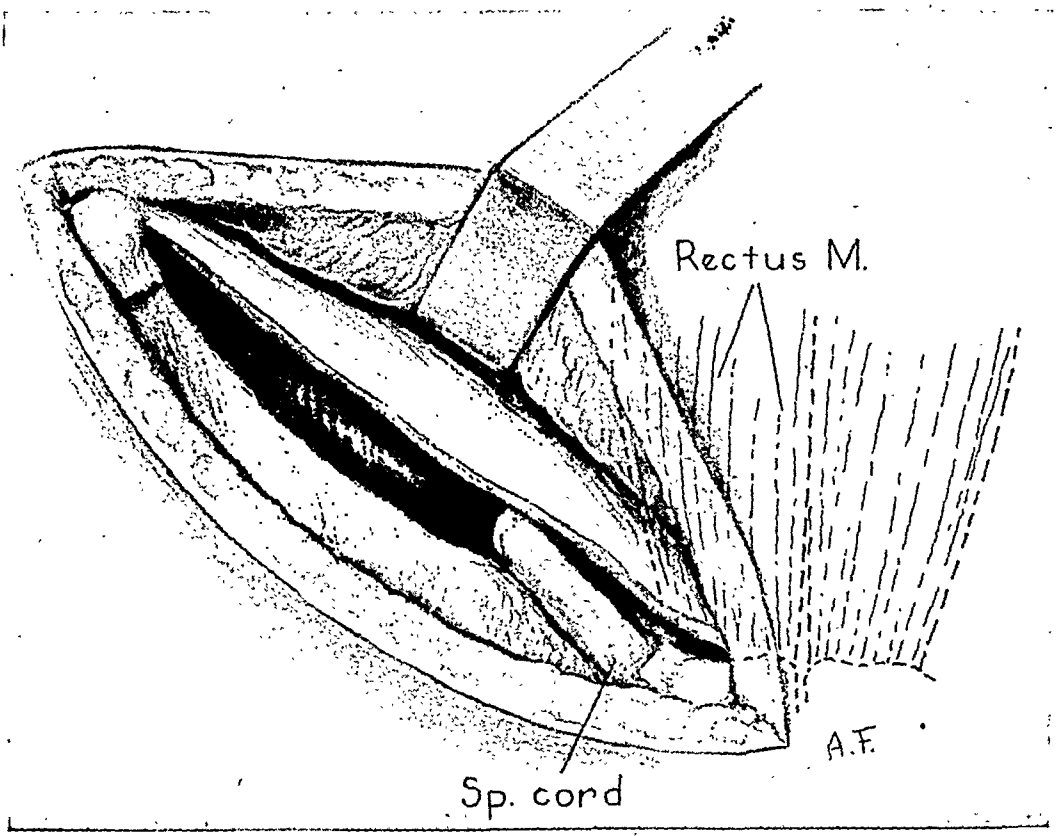



FIG. 29.—The public insertion of the rectus abdominis muscle has been cut. The medial and lateral attachments of the inguinal ligament have been severed. Thus, the anterior abdominal wall is detached from the bony pelvis. Spermatic cord is preserved.

During the first two postoperative weeks the patient's anemia was profound, and did not respond to repeated blood transfusions, liver or iron therapy. Aside from this, the convalescence was uneventful. There was no bowel disturbance or abdominal distention. An indwelling gastric tube was inserted after the patient had fully reacted from the anesthetic; it was attached to Wangensteen suction and left for four days. This was a significant factor in preventing ileus. Tidal bladder drainage was continued for seven days after which the patient had normal bladder control. The wound healed *per primam*, and serous drainage ceased after the 18th postoperative day. The patient was discharged on the 21st postoperative day (Fig. 28).

*Pathology.*—The sciatic nerve was replaced by a bulky, hard, irregular, grayish tumor, which measured 20 x 7 cm. It invaded the following muscles: obturators, gamelli, biceps femoris, semimembranosus, semitendinosus and quadratus femoris. The obturator foramen had been perforated and the pelvic parietes were involved. Throughout the entire extent of the sciatic nerve and its tibial and perineal branches were myriads of neurofibromas. Even the small subcutaneous and muscular branches contained numerous fusi-

form nodules. Microscopic examination revealed the main tumor mass to be neurogenic sarcoma. Many of the nodules which studded the major and minor nerve trunks were also studied histologically and proved to be plexiform neurofibromas.

*Comment.*—This case illustrates malignant transformation of a plexiform neurofibroma of the von Recklinghausen type. These patients should be care-

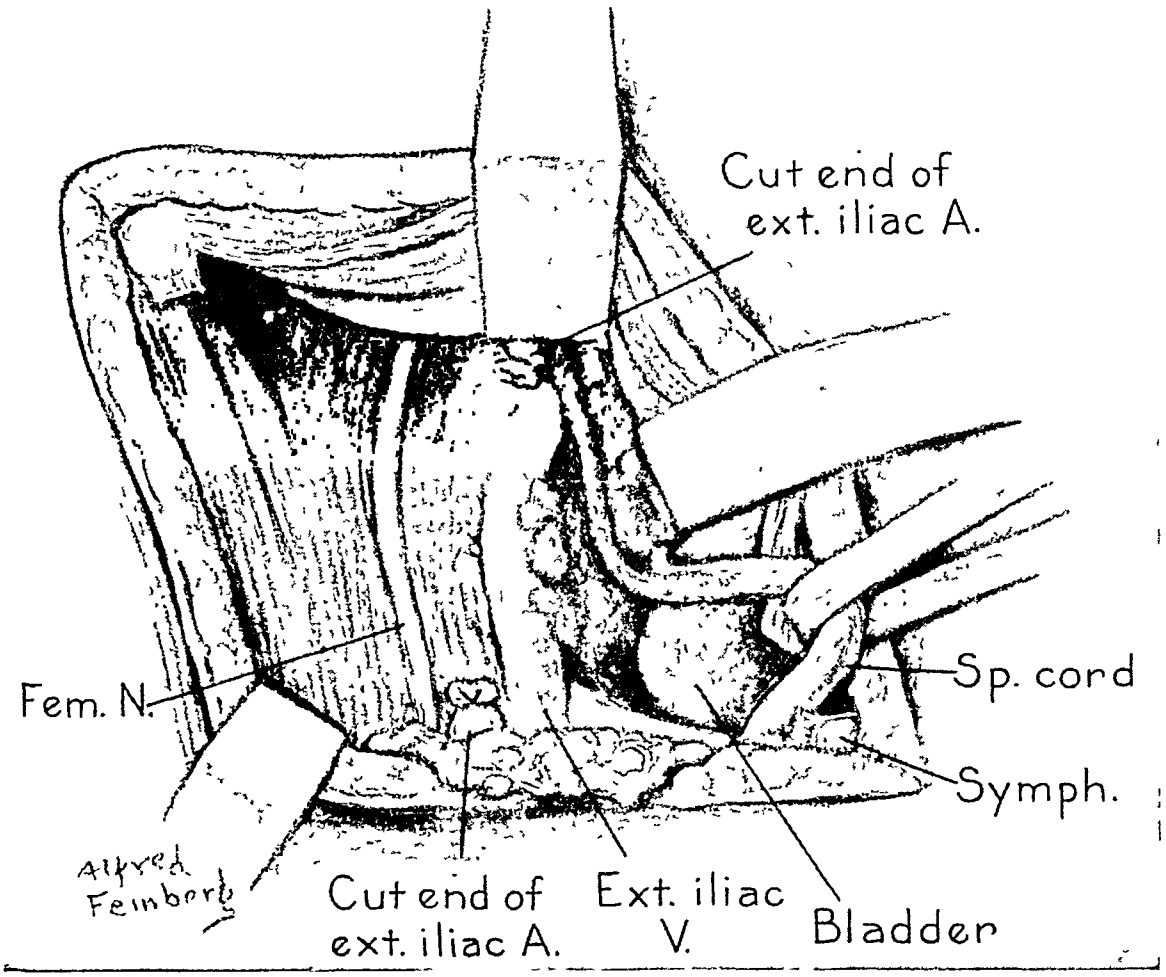



FIG. 30.—The retroperitoneal space has been exposed by pushing the peritoneum, its contents and the urinary bladder upward and medially. The external iliac artery has been ligated and divided. The external iliac vein is not ligated at this time to allow for a maximum return of blood from the limb.

fully examined at frequent periodic intervals so that neurogenic sarcoma may be detected relatively early, before extensive mutilating surgery becomes necessary. The tumor had perforated the obturator foramen. An exploratory operation can always be performed to ascertain such extension. Obviously it was not possible to remove this tumor in its entirety without resorting to amputation through the sacro-iliac joint. This patient might develop other neurogenic sarcomas in the neuromatous nodules of the lumbar plexus.

**Case 5.**—*Sacro-iliac Disarticulation for Periosteal Fibrosarcoma of Ischium.*

D. F., a 45-year-old housewife, was referred to the Memorial Hospital, August 8,

1945, for a tumor of the buttock. She had complained of pain in the lower back, left thigh and groin for nine months. Examination revealed a bulky, stony hard mass involving most of the left buttock. It measured about 15 cm. in diameter. The overlying skin was unchanged and unattached, but the growth appeared to be adherent to the underlying bone. No nodes were palpable in the groin or retroperitoneal space. There was considerable spasm of the muscles of the thigh and leg. Blood count showed a moderate anemia. Roentgenologic studies revealed destruction in the subcapital portion of the neck of the left femur and the presence of a large soft-part mass associated with the bony erosion. Roentgenograms of the lungs were negative for metastasis. Aspiration biopsy was performed and a diagnosis of unclassified spindle cell sarcoma was made.

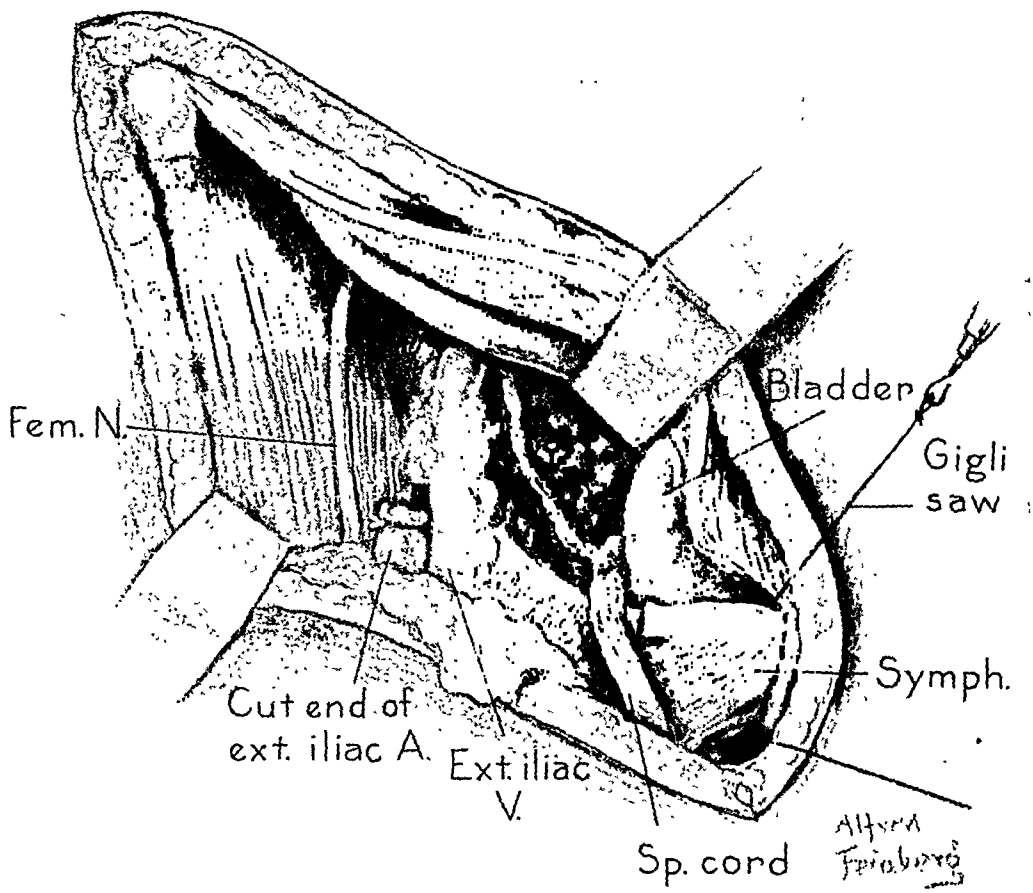



FIG. 31.—The symphysis pubis is skeletonized and then divided with a Gigli saw. The bladder must be retracted well out of the way during this phase of the operation. The symphysis must be clearly identified, otherwise the corresponding or contralateral pubic arch will, instead, be transected. Note that the external iliac vein is still intact.

Left sacro-iliac disarticulation was carried out, August 29, 1945, in the usual manner except that the common iliac rather than the external iliac artery was deliberately ligated. No significant bleeding was encountered anywhere. The usual hemorrhage which follows partition of the pubic symphysis and sacro-iliac synchondrosis did not occur. Bleeding from the parietal branches of the hypogastric artery was sluggish. At the close of the operation the posterior skin flap appeared viable. One thousand cubic centimeters of blood was administered during the operation. The blood pressure was continually stable and at no time did the pulse rate change.

A Levine tube was placed in the stomach as soon as the patient had reacted from the anesthetic and continuous suction was applied. No significant abdominal distention occurred and gastric intubation was discontinued on the fourth postoperative day. Tidal bladder drainage was maintained for one week, after which the patient was able to void spontaneously; the residual urine varied from 75 to 100 cc. for several days after discontinuance of bladder drainage. There was no disturbance of the anal sphincter The postsurgical course was complicated by anemia and severe hypoproteinemia.

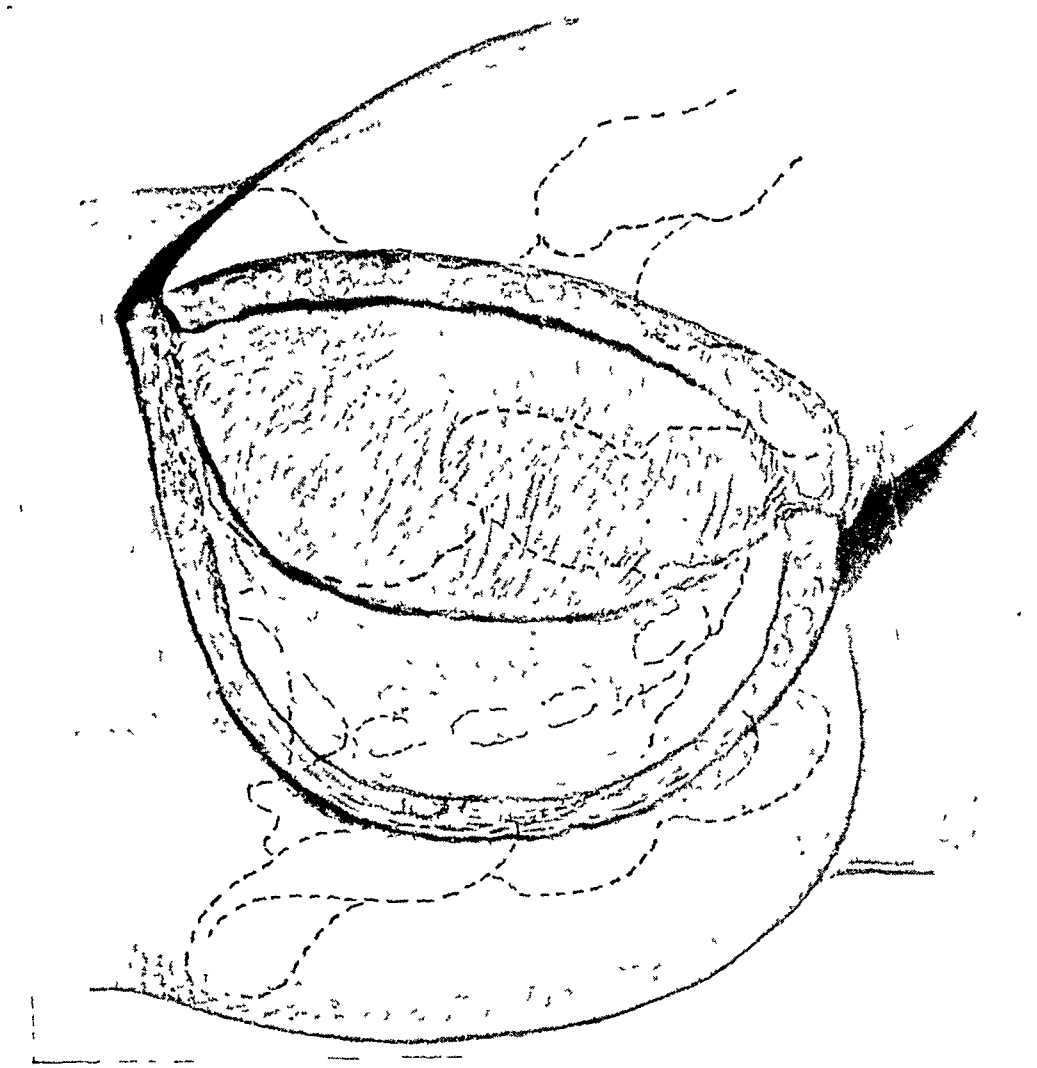


FIG. 32.—The posterior skin flap is developed as far back as the sacrum

On the fourth postoperative day two areas of necrosis were noted on the posterior flap adjacent to the suture line and the wound drained large amounts of thick brown pus (*B. coli*). The eschars were excised three days later, and at this time the anterior half of the posterior skin flap was found to be completely necrotic. A débridement was performed and the underlying fascia was not found to be necrotic. The resultant defect measured 12 x 10 cm. The skin over the sacrum appeared unchanged at all times The wound was cleansed daily, using power sprays and dakinized packs. The infection slowly subsided and granulation tissue appeared. On October 2, 1945, secondary wound closure was performed under intravenous (pentothal sodium) anesthesia. The flaps were approximated without tension, using interrupted sutures of fine steel wire. The wound continued to drain for several weeks but finally healed About one week after the secondary closure, the wound flora was predominantly *B. pyocyaneus*, and this infection responded satisfactorily to

irrigations of one per cent acetic acid. The patient was discharged on the 61st post-operative day.

*Pathology.*—Situated in the upper posterior thigh and extending into the buttock was a well-delineated, but unencapsulated, roughly oval tumor, measuring 11 cm. in longest diameter (Fig. 20). The neoplasm was deeply embedded in the soft parts and was covered posteriorly by the gluteus maximus and hamstring muscles. The lower pole of the growth rested on the quadriceps femoris muscle. Nowhere did the tumor infiltrate the muscle planes. Its external surface was glistening and slightly lobulated and on cut-section was found to be composed of yellowish-white homogenous tissue containing areas of hemor-

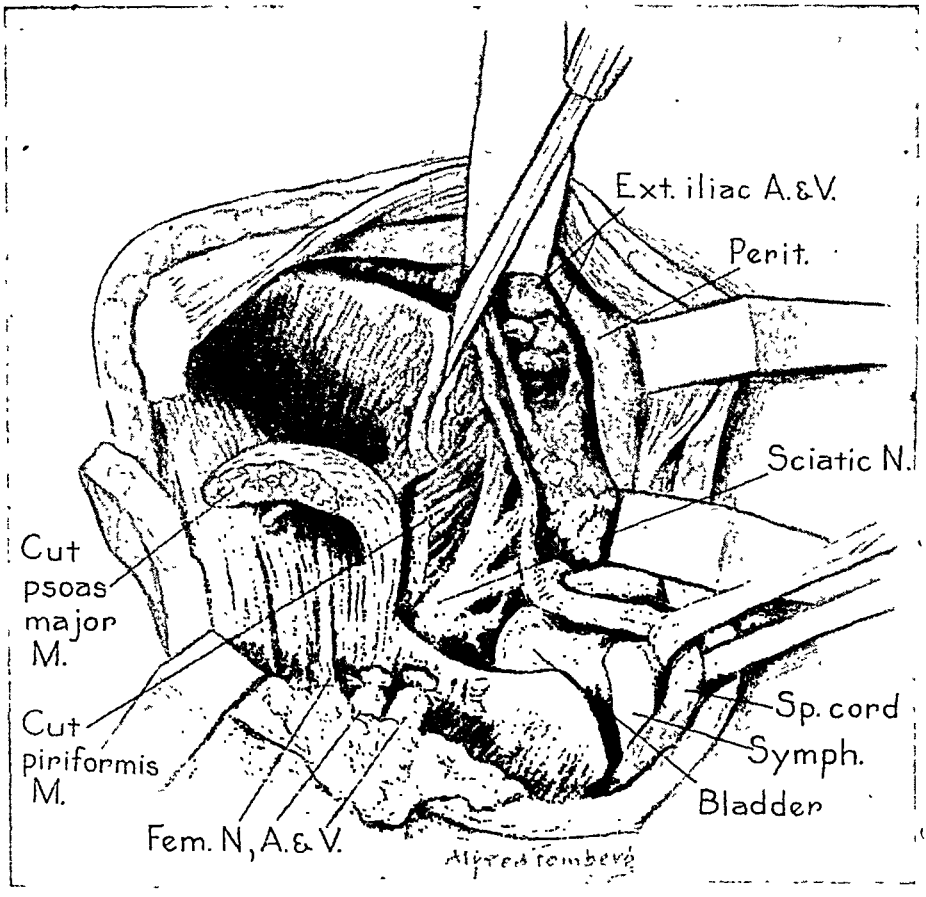



FIG. 33.—Anterior dissection continued. The ilium has been completely skeletonized and the external iliac vein has finally been ligated and divided. The sacro-iliac joint is exposed by transecting and reflecting all the overlying muscles. Disarticulation of this joint is best performed during the anterior dissection-phase of the operation. Bevel of chisel and direction of the instrument must be *away from the midline.*

rhage, necrosis and fibrosis. It was firmly attached superiorly to the soft tissues adjacent to the rami of the pubis and ischium. Anteriorly, in the infrapubic area, the growth was distinctly lobulated and infiltrative, extending to the posterior inferior iliac spine. The capsule of the hip joint and its adjacent soft tissues were involved. The inferior portion of the acetabulum and the ligamentum teres were destroyed by tumor. The obturator foramen had not been perforated. The head and neck of the femur and most of the ischium were also invaded. Microscopic diagnosis was periosteal fibrosarcoma.

COMMENT.—Even though this tumor involved the upper thigh, buttock,

hip joint and a considerable portion of the innominate bone, it was possible to circumscribe and excise it by performing an amputation through the sacro-iliac joint. Although ligation of the common iliac artery assured a relatively bloodless operation, latent necrosis of the posterior skin flap occurred, resulting in extensive and serious wound infection. The ensuing defect was finally obliterated by successful secondary wound closure. Ligation of the common iliac artery was responsible in this case for considerable morbidity and a protracted convalescence.

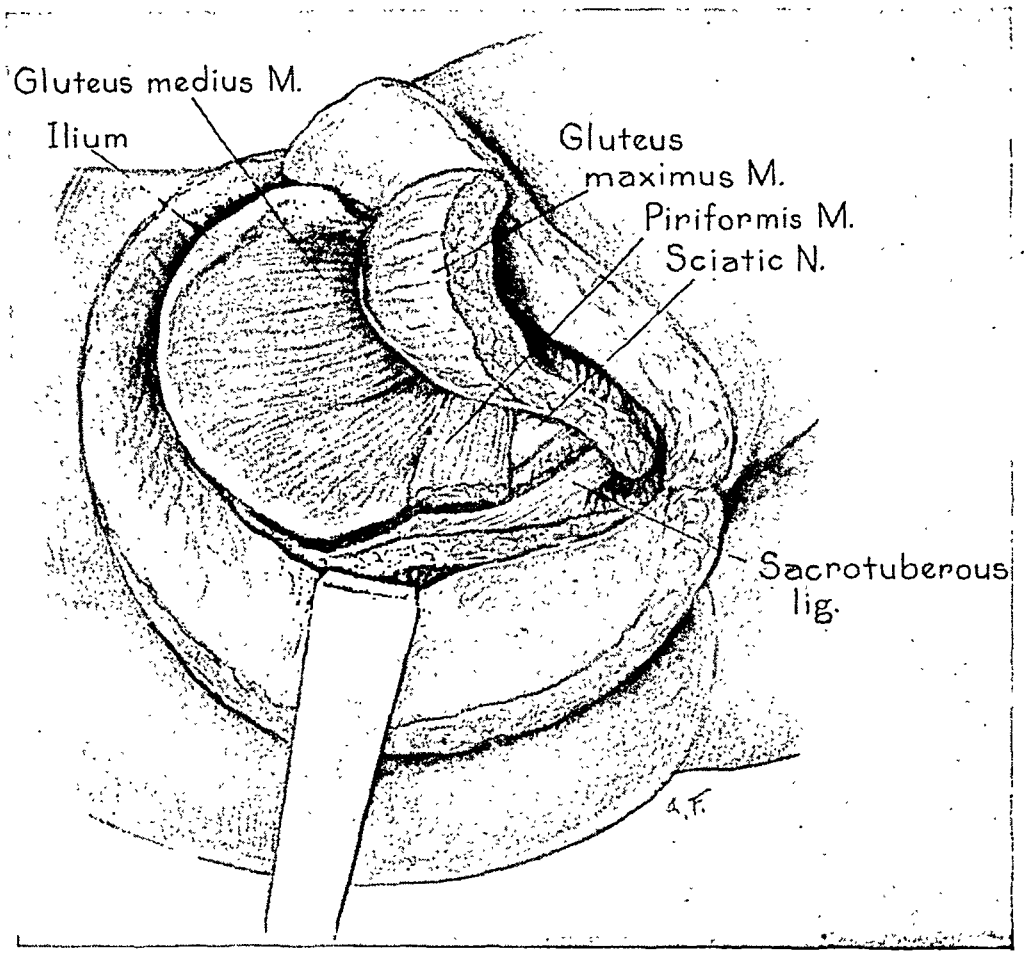



FIG. 34.—Posterior dissection. After partition of the sacro-iliac joint, the patient is turned on the unaffected side and the innominate bone is further mobilized by transecting the sacral muscular attachments. The specimen is now attached to the patient only by the major ligaments of the sacrum and the great nerve trunks of the lumbar and sacral plexus.

If the patient is a very poor risk, where unavoidable hemorrhage and shock might contribute toward an operative death, it is preferable to ligate the common rather than the external iliac artery even though necrosis of the posterior flap is inevitable. Under such cimcumstances the posterior skin flap should be made very thin, denuding it of all subcutaneous fat. A judiciously applied dressing will maintain this large thin skin flap (analogous to a skin graft) uniformly and snugly against the underlying tissues. In this way extensive

necrosis, with subsequent infection and loss of the posterior flap, might be averted.

**Case 6.**—*Sacro-iliac Disarticulation for Extra-osseous Osteogenic Sarcoma of Groin and Thigh.*

E. M., a 57-year-old white male, was first seen at the Memorial Hospital, July 25, 1945, for a tumor of the thigh of one year's duration. Two weeks after the growth was first noted, it was excised and a diagnosis of liposarcoma was made. Accordingly, a course of high-voltage roentgenotherapy was administered. Two recurrences appeared within the ensuing six months, and each of these was treated with roentgenotherapy. After the third recurrence the patient was referred to the Memorial Hospital.

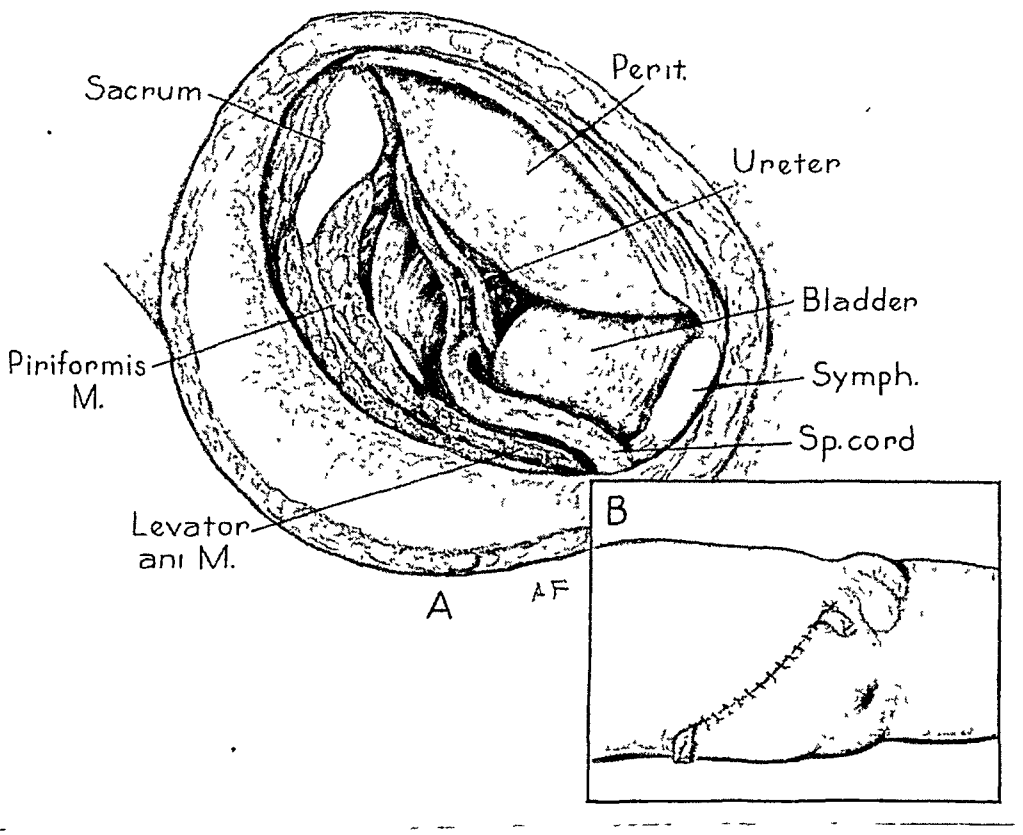



FIG. 35.—(A) Amputation through sacro-iliac joint completed. (B) Wound closure.

On admission, he complained of intense pain in the entire right lower limb, groin, hip joint and perineum. There was much difficulty in moving the affected extremity. The patient had been bedridden for two months, and was consuming considerable quantities of narcotic drugs daily. Examination revealed evidence of past and recent heavy irradiation to the skin of the upper thigh and groin. Situated in the groin and upper inner thigh was an ulcerated, infected, deeply infiltrating tumor. The crater measured 3 cm. in diameter, and its edges consisted of fungating, largely necrotic, friable neoplastic tissue. The inguinal ligament in its distal half was thickened, as was the adjacent portion of the scrotum. Drainage from the ulcerated growth was profuse and foul-smelling. On rectal examination, extensive induration was noted in the right pararectal tissues, suggesting the pres-

ence of tumor. Roentgenologic examination of the bony pelvis, femur and lungs revealed no evidence of involvement. Biopsy of the growth was made and reported extra-osseous osteogenic sarcoma.

Proctoscopic examination was negative. On cystoscopy, several pink, soft, discrete, noninfiltrating masses were seen near the left ureteral orifice and a similar lesion was noted between the ureteral orifices, suggesting a primary bladder tumor rather than direct extension or metastases from the tumor in the groin. Microscopic examination of several biopsy specimens from the bladder revealed epidermoid carcinoma, Grade 1. It was believed that the bladder, urethra, prostate gland and the rectum were not involved by osteogenic sarcoma.

On August 5, 1945, limited cautery excision of the fungating portions of the tumor in the skin was performed in order that daily cleansing of the ulcerated growth could be performed more efficiently. On August 23, 1945, the infection was well-controlled, so that the tumors in the bladder could be safely fulgurated through the cystoscope.

One week later right sacro-iliac disarticulation was performed in the usual manner. Extensive skin damage, due to previous radiation therapy, and marked thickening of the adjacent portion of the scrotum necessitated the sacrifice of some skin on the anterior abdominal wall, one-third of the adjacent scrotum and a small amount of contiguous perineal skin. Many of the anatomic landmarks were either indistinct or entirely obliterated. The spermatic cord, bladder, urethra, prostate gland and rectum were not involved by tumor. There was no intraperitoneal or retroperitoneal extension. Hemorrhage was considerable due to recent radiation therapy and the extensively infected state of the tumor and surrounding tissues. The patient was given 1,500 cc. of blood during the operation, which he tolerated without mishap.

The standard postoperative precautions were taken (indwelling gastric tube attached to suction, tidal bladder drainage, blood and plasma transfusions, correction of water and electrolyte imbalance, vitamin therapy, chemotherapy). No bowel or urinary disturbances occurred, and abdominal distention was only moderate. The postsurgical course was complicated by anemia, hypoproteinemia, wound infection, poor wound-healing and finally osteomyelitis of the remaining pubis. The edges of the medial third of the wound, adjacent scrotum and perineal skin remained reddened and indurated and showed no tendency to heal. A profuse discharge was present (*Proteus vulgaris* predominating).

On the 32nd postoperative day a pocket of pus was discovered in the distal end of the wound and was appropriately drained. Ten days later a swelling was noted in the suprapubic area and the overlying skin was reddened. The patient offered no complaints, there was no temperature elevation, but marked local tenderness was present. Roentgenologic studies revealed evidence of osteomyelitis of the pubic ramus. At operation, a large parapubic and paravesical abscess was evacuated. Curettage of the affected bone was carried out. Subsequent treatment of the wound consisted of dakinization, followed later by activated zinc peroxide packings. Resolution of the infection occurred slowly, and the patient was discharged on the 68th postoperative day, with a 3-cm. sinus in the parapubic area.

*Pathology.*—Situated in the upper medial thigh and groin was an ulcerated deeply infiltrating mass. Cut-section revealed it to be roughly oval in shape, sharply circumscribed but unencapsulated. It measured 7 cm. in longest diameter. The growth extended downward to within 2.5 cm. of the shaft of the femur. Superiorly, it reached to within one centimeter of the capsule of the hip joint and 3 cm. below the ramus of the pubis. At no point did it appear to be associated with any bony structure (Fig. 21). The neoplasm did not involve the obturator foramen. It was largely composed of gelatinous, grayish friable tissue showing extensive necrosis. Firm gritty areas were also present. The central portion of the tumor was necrotic with cavity formation. No osseous or cartilaginous components could be recognized macroscopically. Final histologic diagnosis was extra-osseous osteogenic sarcoma.

COMMENT.—The presence of a second primary malignant tumor (epidermoid carcinoma of the urinary bladder) was discovered during the preoperative investigative period and did not contraindicate a surgical program designed to remove a bulky, recurrent, deeply infiltrating, malignant tumor of the thigh and groin. Operability in this case was borderline due to possible involvement of the rectum. It was reasonably certain, after continued study of the problem, that the rectum was not involved by tumor. If further evidence to decide rectal or pararectal extension was necessary, exploratory celiotomy could have been performed.

The necrotic, ulcerated and infected state of the tumor necessitated a lengthy period of presurgical preparation, including preliminary cautery excision of the fungating portions of the tumor, in an effort to reduce the septic condition of the tissues and to prepare the operative field. Even though amputation included skin of the anterior abdominal wall, scrotum and perineum, it was ostensibly inadequate, for poor wound-healing resulted from the presence of heavily irradiated skin contiguous to the suture line. Wider skin excision, even if followed by the application of an immediate split-thickness graft, would have undoubtedly lessened the morbidity and shortened the convalescence in this instance.

Osteomyelitis of the remaining pubic bone was due to the presence of exposed cancellous bone in a preëxisting soft-tissue infection. Division of the symphysis pubis rather than the contralateral pubic arch would most likely have prevented this unfortunate complication. Obliteration of anatomic landmarks, due to infection, edema and previous heavy irradiation, made exposure and visualization of these structures difficult.

## PROGNOSIS AND END-RESULTS

The prognosis following sacro-iliac disarticulation for malignant tumors will depend on the anatomic type and extent of the tumor, the number of recurrences prior to the operation and the presence of distant metastasis. The soft-part neoplasms which carry the best prognosis following this operation are neurogenic sarcoma and nonmetastasizing low-grade spindle cell sarcoma of the fascial-tendon type. Of the bone tumors, chondrosarcoma offers the most favorable prognosis.

In the present series of six sacro-iliac disarticulations, two were performed for palliation only. Five patients are alive and well, with no evidence of recurrence or distant metastasis at the present writing and one patient (palliation case) died of recurrent disease one year after operation. All of our cases, of course, are relatively recent. With regard to previously reported cases in the literature, one-third of the patients who submitted to this operation because of malignant neoplastic disease were reported to be clinically cured. The follow-up period in many of these cases, however, was most inadequate. The number of carefully followed cases is too few as yet on which to base an accurate and final evaluation of the operation. The accumulated evidence indicates that sacro-iliac disarticulation will prove to be a valuable surgical procedure for

the treatment of extensive cancers of the lower extremity, bony pelvis and pelvic parietes.

## SUMMARY AND CONCLUSIONS

Twenty-five cases of hip joint disarticulation and six of sacro-iliac disarticulation for malignant tumors are reported and analyzed. The principle of exarticulation of an extremity, with excision of the involved regional lymph nodes, for selected cases of malignant melanoma and clinically similar tumors is introduced and illustrated by five cases of hip joint disarticulation combined with deep iliac dissection. Standardized technics for all three operations are described and illustrated.

The postoperative complications specific for cases of amputation through the sacro-iliac joint and their prevention are discussed. These extensive surgical procedures need not be hazardous. There were no operative deaths in this series.

Radical amputations (disarticulations) serve a definite and distinctly useful rôle in the treatment of selected cases of cancer of the lower extremity, buttock, groin, innominate bone and pelvic parietes.

# ABSORBABLE GAUZE IN BONE SURGERY*

## EXPERIMENTAL STUDIES SUGGESTING CLINICAL APPLICATION IN RECONSTRUCTION OF JOINTS

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THE PROPERTIES of oxidized cellulose or cellulosic acid, its absorbability when introduced in the various tissues, and its usefulness when used as an hemostatic packing in wounds of different viscera have been described and discussed in preceding papers. In one of these papers it was mentioned by one of us (Frantz,[11] Surg. Clin. N.A.) that when oxidized cellulose was used in clean experimental fractures there was evidence of delay in bone repair.

We are now reporting our experimental study of the reparative processes of bone in the presence of different types of absorbable sponges—oxidized cellulose (gauze or cotton), human fibrin foam with thrombin and absorbable gelatin ("Gelfoam") with thrombin—used for hemostatic purpose.

Dogs were used for all of the following experiments. Intravenous nembutal anesthesia was employed and the usual aseptic technic observed.

In a first group of experiments in which seven dogs were used, the upper third of the radius was exposed by a muscle-splitting incision through the extensor muscles. After denuding the bone of periosteum, two or three drill holes were made down to the marrow cavity. With the aid of a small chisel these holes were then united so as to obtain a cavity which measured 3 to 4 mm. in width. Bleeding was usually abundant. These cavities were then packed with small pledgets of oxidized cotton. The material was very easy to handle, almost immediately transforming itself into a dark paste which was easy to mold into the cavity, and the hemostatic effect was always very satisfactory. These animals were sacrificed at 14, 37, 40, 42, 103, 103 and 134 days, respectively. As shown in Table I, gross evidence of regeneration of bone was absent until the 42nd day, while at 37 days there was microscopic evidence of proliferation of osteoid. Prior to this date the drill holes were filled by dense fibrous cicatricial tissue showing no tendency towards ossification and containing the basophilic phagocytes characteristic of the tissue reaction to oxidized cellulose.

Because these results suggested that the material under study delayed the

*The work described in this paper was done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Columbia University. The gauze and cotton were supplied by Eastman Kodak Research Laboratories, Rochester, N. Y. (U. S. Pat. No. 2,232,990) through Parke, Davis & Company, Detroit, Michigan.

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healing of bone, we started a new series of experiments, in order further to investigate the influence of oxidized cellulose on bone repair. After exposing the anterolateral surface of the upper half of the radius as in the previous group of experiments, a fracture was produced with the aid of strong bone-cutting forceps. The bone can not be cut at once, with one single stroke of the instrument, but must be gradually divided, biting a few millimeters at a time. In some instances, instead of a single fracture line, we obtained comminuted

TABLE I

DRILL HOLES IN RADIUS

| | | | Repair | | | | | |
|---|---|---|---|---|---|---|---|---|
| S.P. | Days | Material | X-ray | Gross | Micro. | Phagocytes | Polys. | Absorption |
| 22312 | 14 | Oxidized cotton | − | − | − | + | − | − |
| 22383 | 37 | Oxidized cotton | − + | − | + − | − | − | + |
| 22356 | 40 | Oxidized cotton | + − | − | + − | + | − | + |
| 22371 | 42 | Oxidized cotton | + | + | + | + | − | + |
| 22637 | 103 | Oxidized cotton | + | + | + | + | − | + |
| 22638 | 103 | Oxidized cotton | + | ± | ± | + | − | ± |
| 22619 | 134 | Oxidized cotton | + − | ? | + − | + | − | + |

TABLE II

FRACTURES OF RADIUS

| | | | Repair | | | | | |
|---|---|---|---|---|---|---|---|---|
| S.P. | Days | Material | X-ray | Gross | Micro. | Phagocytes | Polys. | Absorption |
| 22876 | 7 | Control | | − | + − | − | − | |
| 22900 | 14 | Control | | + | + | − | − | |
| 22839 | 14 | Oxidized gauze | | − | − + | + | − | +* |
| 22935 | 15 | Oxidized gauze | − | − | − | + | − | +* |
| 22875 | 21 | Oxidized gauze | | − | − | + | − | − |
| 23114 | 68 | Control | + | | + | − | − | |
| 23113 | 91 | Oxidized gauze | − | + | − + | − | − | + |
| 23035 | 12 | Fibrin foam | | − | − + | − | − | − |
| 23076 | 17 | Fibrin foam | − | − | − + | − | − | − |
| 23201 | 56 | Fibrin foam | + | + | + | − | − | + |
| 23244 | 70 | Fibrin foam | + | + | + | − | − | + |

* In these two cases a cystic cavity was found.

fractures in which the bone was broken in several fragments. In this group 11 dogs were used. Of these, three were used as controls and were sacrificed at seven, 14 and 68 days. In four animals, killed at 14, 15, 21 and 91 days, the site of the fracture was packed with oxidized gauze, and in the other four, killed at 12, 17, 56 and 70 days, fibrin foam soaked in thrombin was used. In each instance the sponge was introduced between the fracture fragments and also packed against the denuded surface of the radius, *i.e.*, about one-half of its circumference and approximately 2.5 cm. of its length (Table II). The soft tissues were then approximated with two fascial stitches and the skin closed with interrupted sutures.

As for the physical properties of the materials used, there is no doubt in our minds that oxidized cellulose sponges as compared with fibrin foam sponges

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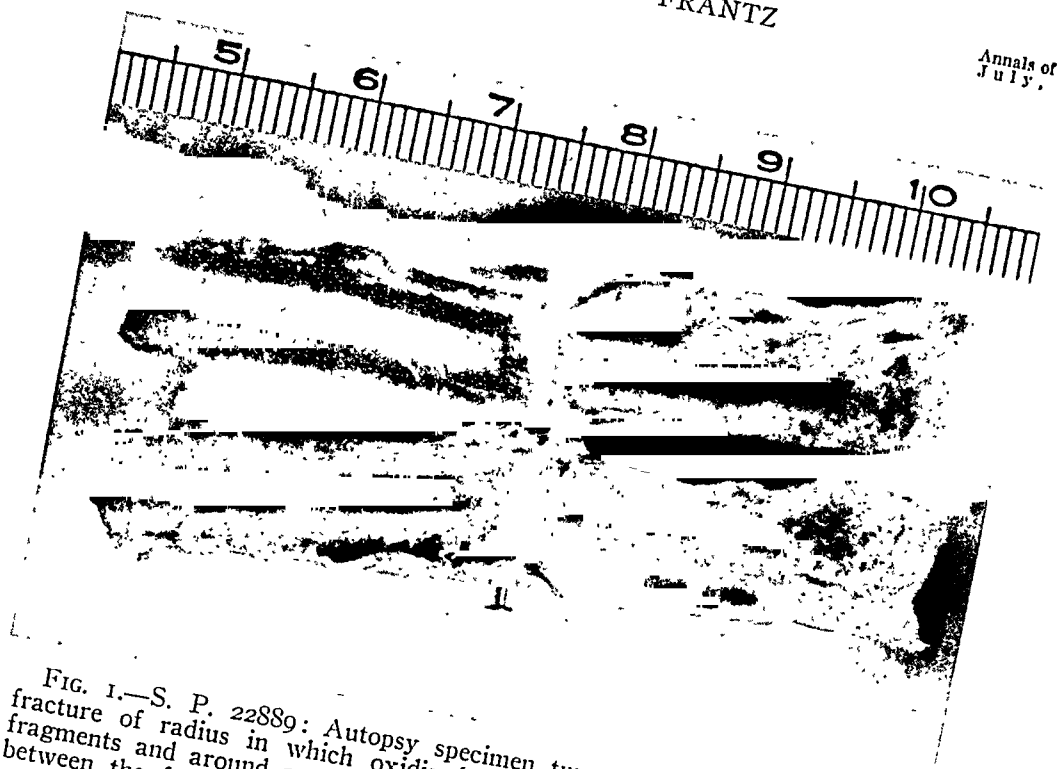



FIG. 1.—S. P. 22889: Autopsy specimen two weeks after experimental fracture of radius in which oxidized gauze was introduced between the fragments and around part of the circumference of the bone. Note cavity between the fragments and between bone and soft parts.

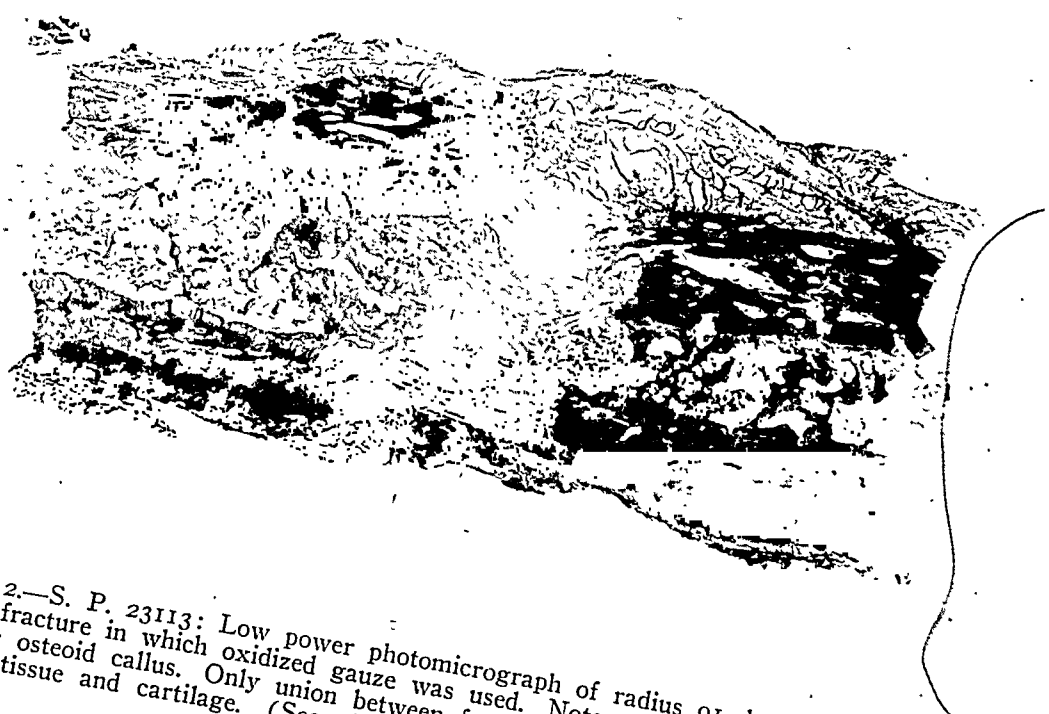


FIG. 2.—S. P. 23113: Low power photomicrograph of radius 91 days after experimental fracture in which oxidized gauze was used. Note practically complete lack of bone or osteoid callus. Only union between fracture fragments is made up of dense fibrous tissue and cartilage. (See also Fig. 3.)

soaked in thrombin, are much easier to handle and to pack in the crevices of the bone. Furthermore, when using fibrin foam one must allow for extra time for the preparation of the solution of thrombin and for soaking the dry fibrin sponge in the thrombin solution. Table II shows that bone repair, when compared with the healing of the control fractures, was delayed in both the oxidized

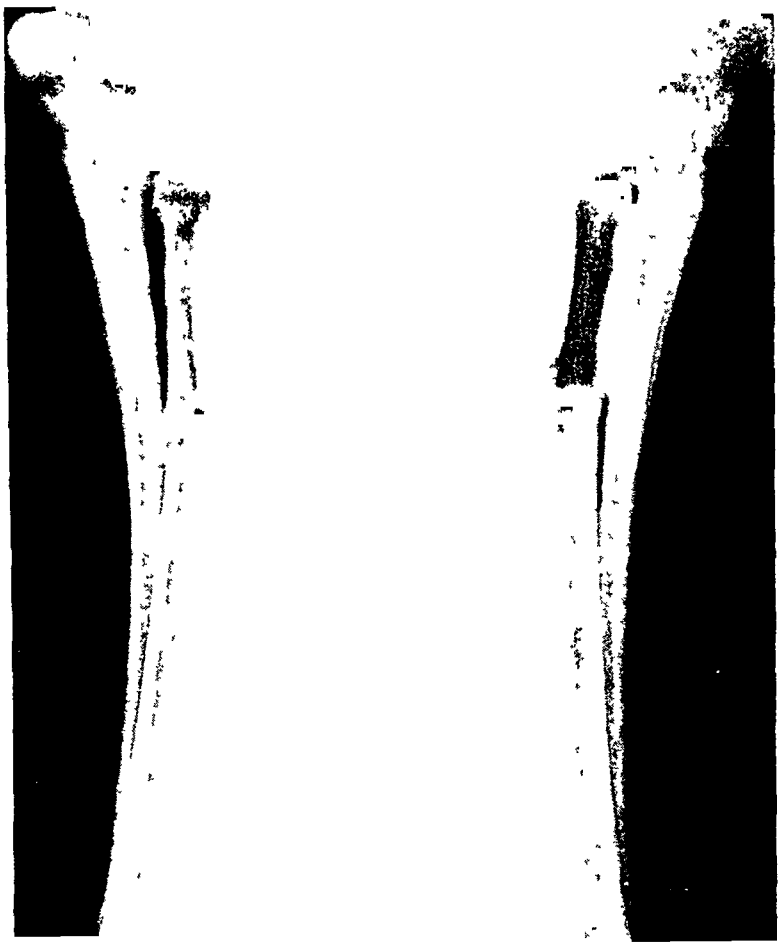


FIG. 3.—S. P. 23113 (left) and 23114 (right) : Roentgenograms of autopsy specimens of left and right front legs of same animal. Left side shows no radiologic sign of callus *three months* after experimental fracture in which oxidized gauze was used. Right side shows calcified callus in *two-months'-old* fracture of radius in which no absorbable material was used.

cellulose and fibrin foam groups. No attempt is made here to compare the effect on bone healing of these two types of sponge as to their relative time factors.

However, we want to describe in detail two cases. In one case (S. P. 22889) a cyst-like cavity containing remains of oxidized cellulose was found surrounding the fracture at 14 days. The portions of bone shaft contained in this cavity appeared free of any soft tissue attachment and did not show gross signs of repair (Fig. 1). Microscopically, a minimal amount of osteoid was present together with the usual typical phagocytes. Another case (S. P. 22935), sacrificed 15 days after production of fracture using oxidized gauze in the

manner described, showed a similar cavity which was lined by flattened cells, making it resemble an adventitious bursa. Also here, there were minimal, if any, microscopic signs of bone repair. No such cavities were observed in the cases in which fibrin foam had been used.

In the cases followed for a longer time where repair had eventually taken place, the osteoid callus was mostly periosteal while between the fracture fragments the union had occurred predominantly by way of fibrous and cartilaginous tissue (Fig. 3). Altogether, reparative tissue in this group of experiments seemed to contain more abundant osteoid in the cases treated with fibrin foam than in those in which oxidized cellulose was used. We realized, however, that individual difference in type and rate of healing as well as differences in the type of fracture obtained might well account for the apparent advantage in favor of fibrin foam. In some of the cases, the lack of proliferation of osteoid was particularly striking in proximity to the collections of basophilic phagocytes typical of the tissues in which oxidized cellulose has been introduced. We shall return later to this interesting point.

These preliminary results induced us to attempt to devise a type of experiment in which we could compare, in the same animal, the influence on bone healing of different types of absorbable materials. This would eliminate the rôle played by possible individual differences in tissue reactions and would also allow the use of a smaller number of animals than would be otherwise required. The method we used, which in our opinion, was satisfactory is as follows:

Under intravenous anesthesia with nembutal, the animal was placed on its left side. The right hemithorax was shaved and prepared. Three or four ribs (6th to 9th) were identified by palpation and their place marked on the skin with gentian violet. An oblique incision, about 7 cm. long, was then made running cephalocaudad and postero-anteriorly, approximately between the posterior and the anterior axillary line. The anterior margin of the latissimus dorsi muscle was then identified, the muscle was retracted backward and, after incising the underlying loose areolar tissue, the ribs were easily exposed. The periosteum was then incised and stripped away all around the bone for a length of 3 cm. With some care and patience, this maneuver is easily executed without perforating the underlying parietal pleura which is very thin. With bone-cutting forceps, and while protecting the pleura with the handle of a scalpel, a linear fracture of the ribs was then produced. The absorbable material was then packed between the fracture fragments and wrapped around the portion of bone denuded of periosteum. No attempt was made to close the periosteum over the fractured ribs, but the loose overlying areolar tissue was approximated with two or three fine silk stitches. A similar control fracture was made in which no absorbable material was used. The latissimus dorsi muscle was then replaced so as to cover the sites of fracture and anchored with a few interrupted sutures. The skin was closed with a running stitch.

We performed this operation upon eight dogs. In none was the pleura damaged and all survived, showing only signs of mild respiratory distress for

the first two or three days. No pleural effusion was found in any of them at autopsy. As Table III shows, in four of these animals, sacrificed at 8, 24, 42 and 52 days, oxidized cellulose and fibrin foam were tested; in the other three, sacrificed at 21, 42 and 56 days, fibrin foam and absorbable gelatin sponges soaked in thrombin were used. In all animals one of the fractured ribs was used as control. In the eighth dog, in four ribs instead of fracture a segment 1 cm. long was resected and the gaps thus obtained were filled with oxidized

TABLE III

EXPERIMENTAL FRACTURES OF RIBS

| S.P. | Days | Material | Repair: X-ray | Repair: Gross | Repair: Micro. | Phagocytes | Polys. | Absorption | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 23019 | 8 | Fibrin foam | − | − | − | − | − | − | |
| | 8 | Ox. gauze | − | − | − | + | − | + | Cystic cavity |
| | 8 | Control | − | − | − + | − | − | − | Some osteoid |
| 23100 | 24 | Fibrin foam | + − | − + | + − | − | − | + | Osteoid and cartilage |
| | 24 | Ox. gauze | − | − | − + | + | − | + | Cystic cavity, some periosteal osteoid |
| | 24 | Control | + − | + − | + | − | − | − | Osteoid and cartilage |
| 23165 | 42 | Fibrin foam | + | + | + | − | − | + | Osteoid, cartilage and fibrous tissue |
| | 42 | Ox. gauze | − | − | − + | + | − | + | Almost entirely fibrous callus |
| | 42 | Control | + | + | + | − | − | − | Osteoid, bone and cartilage |
| 23229 | 52 | Fibrin foam | + | + | + | − | − | + | Union: Bone and osteoid |
| | 52 | Ox. gauze | − | − + | − + | + | − | + | Cartilage and fibrous tissue |
| | 52 | Control | + | + | + | − | − | − | Bony union |
| 23323 | 21 | Fibrin foam | − | − | + − | − | − | − | Some periosteal osteoid and cartilage |
| | 21 | Gelatin | − | − | + − | − | − | − | Some periosteal osteoid and cartilage |
| | 21 | Control | − | + − | + − | − | − | − | Some periosteal osteoid and cartilage |
| 23422 | 42 | Fibrin foam | + | + − | + | − | − | + | Osteoid and cartilage |
| | 42 | Gelatin | + | + − | + | − | − | + | Osteoid, cartilage and some bone necrosis |
| | 42 | Control | + | + − | + | − | − | − | Osteoid and fibrous tissue |
| 23479 | 56 | Fibrin foam | + | + | + | − | − | + | Bone and cartilage |
| | 56 | Gelatin | + | + | + | − | − | + | Bone and some cartilage |
| | 56 | Control | + | + | + | − | − | − | Bone and fibrous tissue |
| | | | RESECTION OF SEGMENT OF RIB | | | | | | |
| 23491 | 56 | Fibrin foam | + − | + | + | − | − | + | Little osteoid, cartilage and scar |
| | 56 | Gelatin | + − | + | + | − | − | + | Little osteoid, cartilage and scar |
| | 56 | Gauze | − | − | + | + | − | + | Mostly fibrous callus |
| | 56 | Control | + − | + | + | − | − | − | Large callus, osteoid and cartilage |

gauze, fibrin foam or absorbable gelatin sponge. At autopsy, the fracture sites when examined from the pleural surfaces, presented themselves as rounded swellings covered with shining pleura. These swellings were due in part to the callus, but in great part also to some overlapping of the fractured ends present in all cases, presumably caused by the respiratory movements and by the contractions of the intercostal muscles.

In spite of the fact that oxidized cellulose was the material that apparently was absorbed in the shortest period of time (absorption almost complete at eight days as compared with 21 days for fibrin foam and gelatin sponge), the

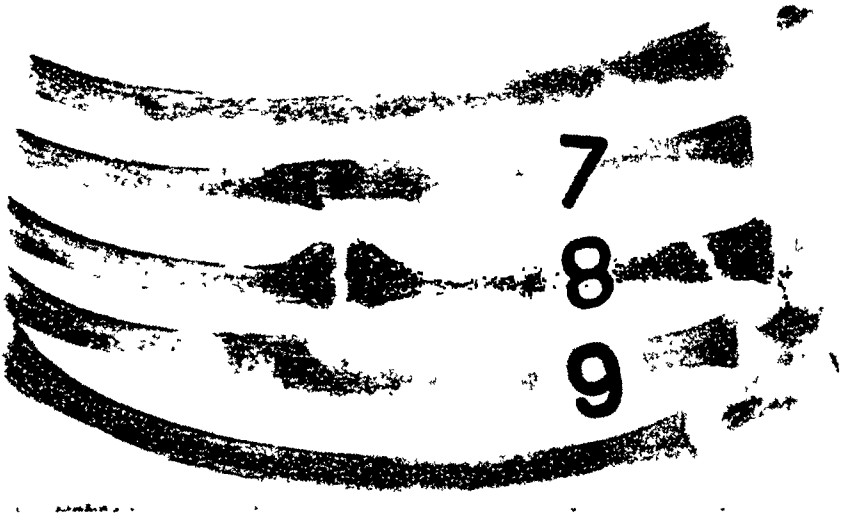



FIG. 4.—S. P. 23165: Roentgenogram of autopsy specimen 42 days after experimental fracture of ribs 7, 8, 9. Note the fairly good calcified callus in ribs 7 (fibrin foam) and 8 (control) as compared with the malunion at 9 (oxidized gauze).

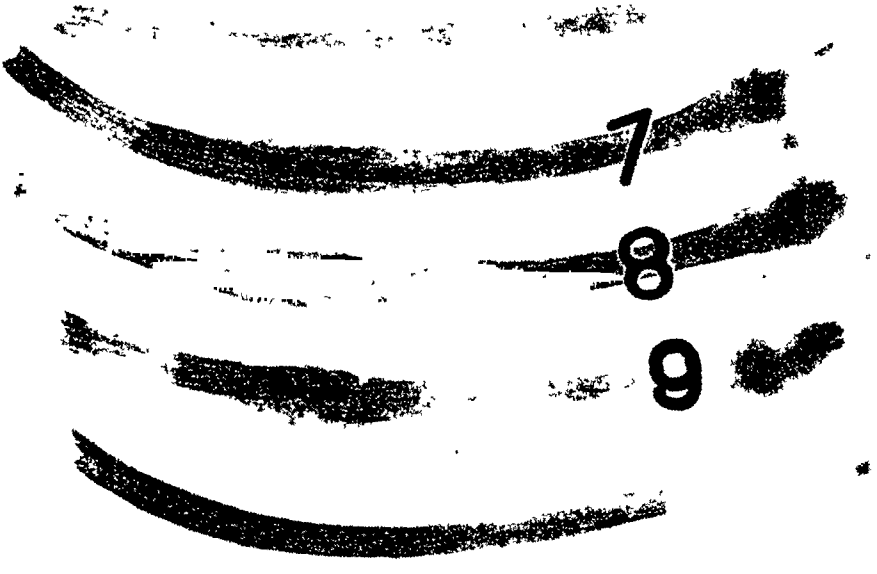



FIG. 5.—S. P. 23229: Roentgenogram of autopsy specimen 52 days after experimental fracture of ribs 7, 8, 9. Note the excellent callus at ribs 7 (fibrin foam) and 8 (control) as compared with the incomplete calcified callus at 9 (oxidized gauze).

reparative processes were consistently slowed down in the fractured ribs in which oxidized cellulose was used. In all cases, from eight to 56 days, these ribs when examined at autopsy showed some persistent mobility at the frac-

tured site and roentgenograms showed that the amount of calcified callus was always less than in the controls and in the fractures in which one of the other two absorbable materials had been used (Figs. 4 and 5). Microscopically

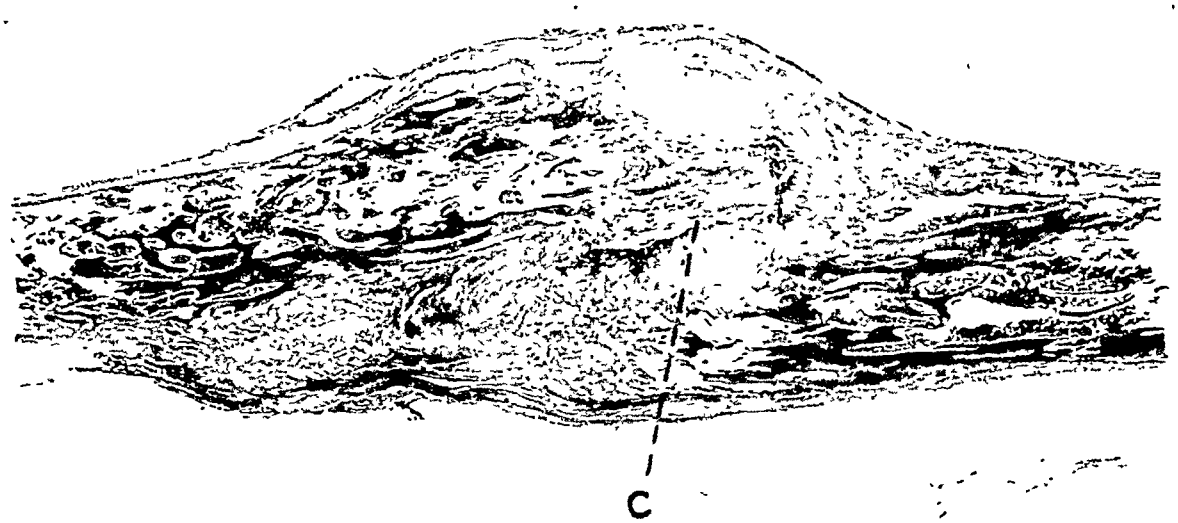



FIG. 6.—S. P. 23229: Low power photomicrograph of 9th rib 52 days after experimental fracture in which oxidized gauze was used. Note scanty osteoid. The tissue which joins the bone fragments consists mainly of fibrous tissue and few islands of cartilage. A small cavity is still present (C).

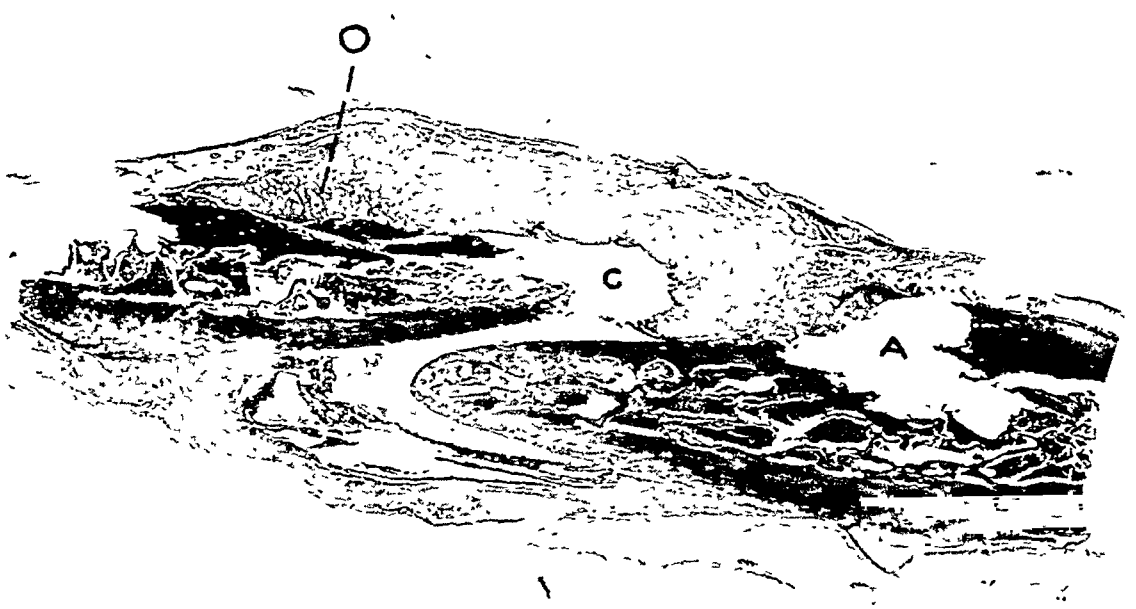



FIG. 7.—S. P. 23100: Low power photomicrograph of a fractured rib 24 days after experiment. Oxidized gauze was used in this rib. Note cavity (C) surrounded by a fibrous tissue capsule and containing the free ends of the fractured rib. Except for a small area of osteoid at (O) there is no histologic sign of bone repair. The space (A) is an artefact. Controls: (not illustrated) Simple fracture and fracture with fibrin foam interposed showed no cavity (See Table III).

(Fig. 6), the amount of osteoid in the callus was always minimal and the repair occurred mostly through fibrous scar containing islands of hyaline cartilage. In the dog sacrificed at the 8th day, necrotic portions of bone could be

seen in the area where the absorbable material had been contained. Furthermore, in two cases (eight and 24 days) a cyst-like cavity was found surrounding the fractured ends, resembling those that occurred in the experiments already described with oxidized gauze in the fractured radius (Fig. 7). The healing of the fractures in which fibrin foam was used did not, in these experiments, show any appreciable delay as compared with the controls (see Table III). No cavities were formed around the fracture sites, the mobility of the fragments was almost absent starting at 24 days and the roentgenographic features of the callus were comparable with those of the control fractures at

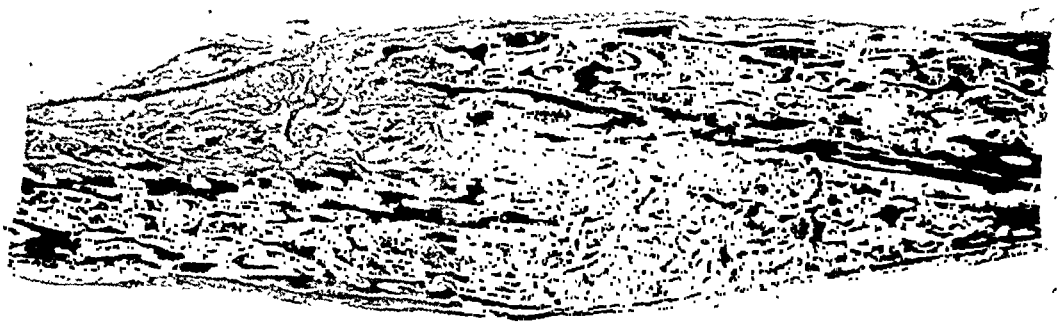


FIG. 8.—S. P. 23229: Low power photomicrograph of 7th rib 52 days after experimental fracture in which fibrin foam was used. Note the excellent bony union in spite of the overlapping of the fragments.



FIG. 9.—S. P. 23229: Low power photomicrograph of 8th rib 52 days after experimental fracture. No absorbable material used (control fracture). Note excellent bony union in spite of slight overlapping of fragments.

corresponding dates (Figs. 4 and 5). Microscopically (Figs. 8 and 9), the reparative process did not seem to be interfered with by the presence of fibrin foam. As a matter of fact, in one instance (eight days) there was evidence of invasion of fibrin foam by the fibroblasts of the host, as would be expected to occur in autogenous fibrinous clot.

Those fractures in which the absorbable gelatin sponge was used showed, in our experiments, a slight delay in healing as compared with those treated

with fibrin foam and with the controls, but in no case as marked as those treated with oxidized cellulose. Some mobility of the fragments was still present at 42 days, but at this date the roentgenograms already showed a good callus. The reparative process consisted of good proliferation of osteoid, cartilage and fibrous tissue without signs of irritation by the foreign material (Fig. 10).

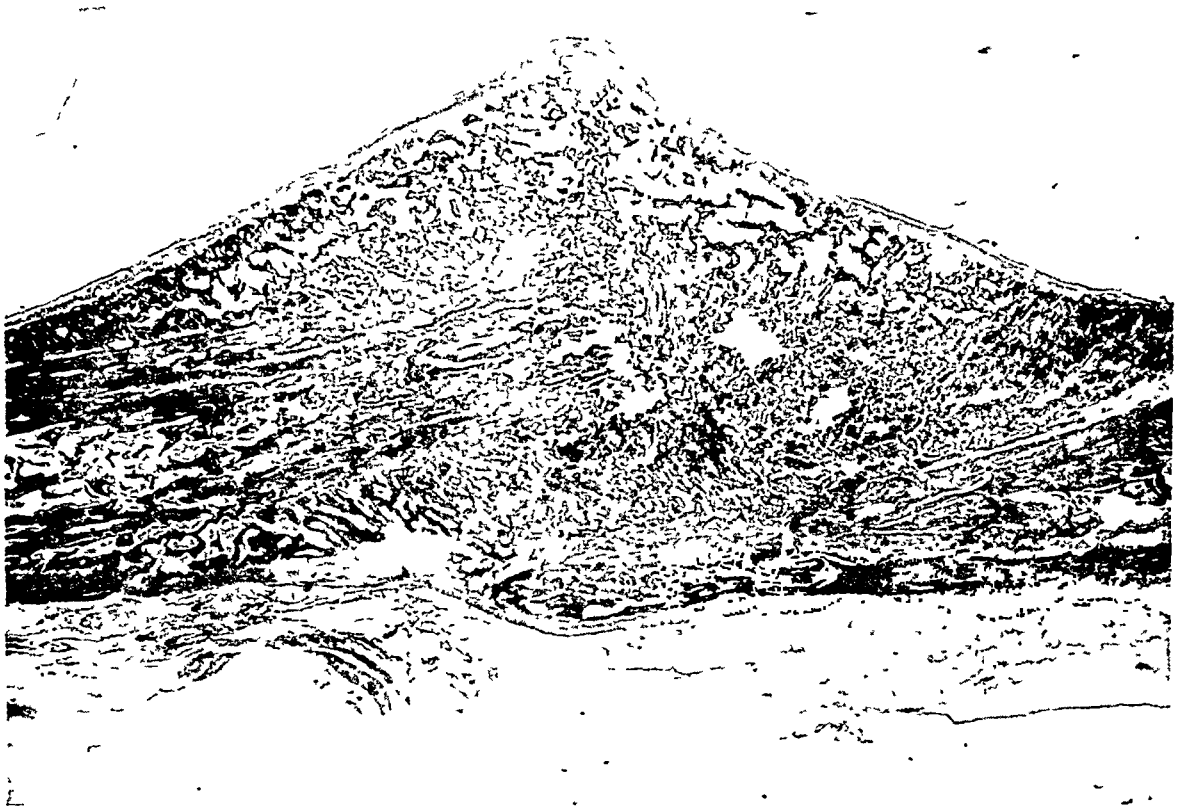


FIG. 10.—S. P. 23479: Low power photomicrograph of rib 56 days after experimental fracture in which absorbable gelatin sponge (Gelfoam) was used. Good bony and osteoid union.

COMMENT.—There seems to be little doubt that the presence of oxidized cellulose in the immediate vicinity of a fracture interferes with the normal processes of repair of bone. By what mechanism does this occur? The material is slightly acid and it probably retains its acid reaction even after having been partly broken down and phagocytized. This is suggested by the fact that the cytoplasm of the characteristic phagocytes, which are present in tissues following introduction of oxidized cellulose, is always more or less basophilic. These phagocytes disappear from the tissues very slowly. In these bone experiments, some phagocytes were still to be seen in the specimens of animals sacrificed 56 days after operation. It is also worthy of mention that in several of our microscopic preparations we had the impression that the least bone repair occurred in proximity to the collections of these basophilic cells. It becomes natural, therefore, to think that the interference with bone healing might depend on a low local $p_H$. This would almost certainly damage already formed bone and interfere with the concentration of inorganic calcium salts,

which is a prerequisite for the formation of new bone. It is also possible that there is interference with activity of the bone phosphatase. We have, however, made no *p*H determinations nor phosphatase determinations in the tissues in these experiments.

From these results we must conclude that in clean bone surgery in which rapid formation of callus is desired, the use of oxidized cellulose as hemostatic packing is contraindicated. Fibrin foam or absorbable gelatin sponge soaked in thrombin are certainly preferable.

For hemostasis in open contaminated or infected wounds of bone oxidized gauze could be used as a temporary packing of large bleeding cavities. As already explained, in preceding publications, it has the advantage of easy removal without causing further bleeding. Furthermore, because of its solubility in the tissue fluids, it never acts as a cork which would transform an open contaminated wound into a closed infected cavity.

Recognition of the peculiar property of oxidized cellulose, *i.e.*, that of interfering with the repair of bone, without any further harmful effects on the tissues immediately suggested its use whenever it is desirable to prevent or at least to delay ossification.

Many applications can certainly be found. The most important one in our opinion is the use of oxidized cellulose in the surgical reconstruction of ankylosed joints, or in general, in those surgical procedures in which the possibility of a postoperative ankylosis is envisaged.

Following our suggestion, arthroplasty operations employing this absorbable material have already been performed by some surgeons associated with this institution. The results to date, judging from the preliminary communications that we have received, are encouraging.

SUMMARY

Oxidized cellulose, fibrin foam, and absorbable gelatin sponges have been used in experimental fractures of bones, and their effects on bone healing have been compared. Oxidized cellulose, possibly because it lowers the local *p*H, interferes considerably with the repair of bone. The utilization of this property of oxidized cellulose is suggested in arthroplasty procedures and other bone operations in which a delayed ossification is desirable.

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# MANAGEMENT OF LATE HEAD INJURIES

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AND

Captain William G. Peacher, M.C.

Certain technical advances have appeared since World War I, which not only allow a more refined neurologic diagnosis, but also considerably facilitate the neurosurgical management of cranial wounds sustained as the result of modern warfare. The former include encephalography, ventriculography and electro-encephalography. Among the latter are electrocoagulation and fibrin foam for hemostasis; tantalum foil and fibrin film as dural substitutes (and to minimize meningocerebral cicatrices); tantalum plate for cranioplasty; and the sulfonamides and penicillin for prophylaxis and control of infection.

These methods were at first available only in the various Neurosurgical Centers in the Zone of Interior. However, in the later phases of the European and Pacific Theaters of Operation, these procedures and materials were utilized in several designated General Hospitals overseas. Fibrin foam was also distributed to the various surgical auxiliary units and a portable electro-encephalogram was being investigated for use in the Field.

A considerable number of casualties with cranial defects and neurologic sequelae have been evacuated to the States for further neurosurgical diagnosis, treatment and rehabilitation. It is not our purpose to review the literature on this subject at the present time; rather we wish to state our experiences in the management of these conditions and the results obtained.

These studies were carried out initially at Brooke General Hospital, Fort Sam Houston, Texas, beginning in April, 1942 and continued at McGuire General Hospital, Richmond, Virginia, on the transfer of the writers in February, 1945. Complete investigation of each patient from every standpoint, including electro-encephalography and encephalography was made on admission.

We have now had experiences with 254 cranioplasties, in which tantalum was used for repair. Two hundred thirty-eight were secondary to craniocerebral injuries, 187 of which were a direct result of wounds sustained in action. The majority of this group were due to shell fragments, preliminary débridement having been accomplished overseas. All defects measuring 3.5 cm. or more in diameter, were revised according to present Army regulations, as well as taking into consideration the usual indications for operation, including the smaller deformities. The remaining procedures were performed after craniotomies for the following conditions: Trigeminal neuralgia, 4; osteomyelitis, 3; osteoma, 3; increased intracranial pressure, 2; meningioma, 2; eosinophilic granuloma, 1; and abscess, 1.

The majority of our earlier cases were repaired under a general anesthetic, and this method is still preferred in those defects involving the squamous portion of the frontal bone. Novocaine local anesthesia has been used in the other

patients. The previous craniotomy incision had usually been irregularly linear or triradiate in appearance and was generally suitable for operative exposure. Old scars were revised and plastic surgery was performed as indicated, taking care not to create too much tension during closure of the wound, which predisposes to incisional necrosis and secondary infection. An occasional horseshoe-type scalp flap may be necessary, particularly, in those deformities involving the squamous portions of the temporal bone for adequate exposure. However, this incision should be avoided if incorporating a significant amount of scar in its base due to possible subsequent necrosis from inadequate blood supply. This was well demonstrated in one of our cases, in which the skin flap had to be subsequently replaced by a split-thickness graft.

Following retraction of the skin edges, the periosteum is carefully separated from the underlying dura, insofar as this is possible. The pericranium can then be sutured over the plate as a separate layer during closure for additional fixation and protection. We have entered the dura in 79 instances and introduced tantalum foil in the subdural space. Decision in this respect will depend upon the size and shape of the defect, proximity to the venous sinuses, electroencephalographic and encephalographic findings, focal signs and symptoms, amount of gross scar at operation, presence of complications, such as infection, *etc.* The advantages derived from opening the dura are numerous. It allows a more accurate evaluation and estimation of prognosis in a given individual, such as those with dysphasia, hemianopsia, *etc.* It facilitates the treatment of such conditions as cerebrodural and cortical scars, porencephaly, *etc.* It discloses the actual site of pathology, allowing inspection, palpation, careful exploration of the extent of the lesion with the ventricular needle and biopsy if desired, thus, supplementing the electro-encephalogram, encephalogram and neurologic examination. It allows the removal of bony or metallic foreign bodies in presence of infection or focal signs. We have preferred to use tantalum foil in all cases, in which the dura has been entered, to prevent further development of a meningocerebral cicatrix, as previously outlined.[11] Fibrin film would serve a similar purpose, but is not as yet commercially available. Tantalum foil has been used in contaminated fields without difficulty, but rarely suppuration will occur, necessitating removal, as shown in two of our cases. Further, infection has occurred as often epidurally without extension into the subdural space in the presence of foil, so this factor alone should not contraindicate its use.

In those cases in which the dura has been entered there have been varying degrees of cerebrodural scar present. This is always carefully dissected free in all directions within and beyond the confines of the incision. This is facilitated by removal of ventricular fluid. The significance of this procedure will be difficult to determine until a long term follow-up on the cases studied can be accomplished. It is expected that although a cortical lysis has been performed which operates to reduce the possibility of posttraumatic complications, such as epilepsy, headaches, *etc.*, these conditions may well develop later from a scar within the brain substance itself.

Relatively early resection of this meningocerebral cicatrix, or its avoidance by application of a dural substitute at the time of injury, with complete primary excision of contused and lacerated brain, when and where possible, may do much to obviate the development of intrinsic cortical scar. This process, once started, tends to increase through the years by extension of blood supply and connective tissue from the meninges to the underlying cortex. Although long-term results are not available in these cases, it is felt that cortical excision for focal epilepsy will not only tend to reduce the actual number of seizures, but also facilitate the medical management with anticonvulsive therapy. Prophylactic surgical therapy in patients presenting focal electro-encephalographic, encephalographic and neurologic evidence of epileptogenic lesions, but without clinical seizures has not as yet been attempted.

The preparation and insertion of tantalum has been described previously by one of us,[10] and more recently by Woodhall and Spurling,[14] who further include the various indications and other methods of cranioplasty. Their series of 79 cases is the largest yet published and the results have been quite satisfactory.

A one-stage procedure is preferred in our cases. Only two of the earlier patients were operated upon in two stages. There appears to be no particular advantage in preparing the plate preoperatively or fabrication at the time of surgery, an equal number of each being on record in our series. The former method conserves time, but occasionally, even when a model has been carefully made, the tantalum is found to be unsatisfactory at operation. This is particularly true in those deformities involving the squamous portions of the frontal bone, including the supra-orbital ridges, which are difficult to restore to perfect anatomic continuity. Preparation of the plate at operation will have its greatest advantage in the immediate repair of acute head injuries. One should develop the facility of beating plates to contour because of such situations.

The inlay technic, in which the plate was inserted in a ledge created along the presenting outer table of the bone with further fixation by tantalum wedges was followed in the first 180 cases. A secondary repair for slipping of the tantalum was necessary on two occasions in our early experience. We have recognized no gross operative or neurologic residuals following the manipulations necessary during the above described procedure. The remaining skull defects were repaired by the onlay technic. In these instances the plate is fashioned in the usual manner, slightly larger than the defect over which it is placed, with or without fixation (tantalum wedges, screws or wire). We have used wedges throughout in lieu of wire. Screws have not as yet become generally available. This, again, is a more rapid method and especially adapted to the treatment of acute craniocerebral wounds, and in those situations in which the presenting bony margins are extremely thinned, such as the squamous portions of the temporal bone. However, the inlay technic is still preferred in the supra-orbital defects because of the more satisfactory cosmetic result obtained.

We can see no advantage in perforating the tantalum plate. This has been suggested to allow fluid interchange, to allow scar formation between the scalp

and dura and to facilitate the administration of penicillin in event of an infection. It has also been demonstrated that tantalum can be used effectively in soiled fields,[10] but the pre- and postoperative preparation of the patient with sulfadiazine and/or penicillin must be stressed. Further, although not invariable, it has usually been necessary to remove the plate once infection has occurred following cranioplasty.

We must reëmphasize the necessity of exenterating the mucous membrane of the frontal sinus and occluding the ostium of the nasofrontal duct to avoid a potential source of infection. One case was unsuccessfully revised on two occasions for an extradural pneumatocoele and finally controlled only after scarifying the nasal opening of the passageway from the frontal sinus.

Many of these cases have collected subgaleal and subcutaneous fluid postoperatively in spite of careful hemostasis, closure and compressive dressings. Repeated aspiration under questionably aseptic conditions may possibly have led to infection in two cases, although there is always a possibility of latent organisms at time of operation. We have accordingly drained our more recent cases for 24 to 48 hours, with satisfactory results.

We wish to comment on the rarity of cases evacuated to us with brain abscess or cerebral hernia, which has been felt due to careful, thorough preliminary débridement.

The electro-encephalogram has been of considerable value in cases of this type, particularly in the detection of subclinical epilepsy. Experience in the interpretation of this procedure is essential, however, if it is to be relied upon for diagnosis and prognosis.

Encephalography has been performed routinely in all our cases, and we have found it helpful in giving additional useful information, such as presence of ventricular shift, porencephaly, internal hydrocephalus, *etc.*, which may alter the subsequent operative procedure. The lumbar route, under pentothal anesthesia, has been used, although some prefer the cisternal technic to minimize reaction. We have further prepared the scalp the morning of the encephalogram and proceeded with the cranioplasty the following day in many of these cases without intensification of symptoms, and this sequence also shortens the actual length of hospitalization. Tapping of the ventricle at cranioplasty further tends to diminish postoperative headaches by release of the previously injected air or oxygen.

The neurologic residuals include the various signs and symptoms dependent upon the site of central nervous system trauma and the degree of permanence can usually be estimated three to four months following the trauma. These do not include the possibility of convulsions or the period of improvement which will result from the intelligent and intensive rehabilitation of speech. The latter often requires one to two years. All patients receive intensive reconditioning, including an educational, vocational and recreational program, together with occupational and physical therapy as indicated prior to completion of maximum benefit of hospitalization.

The various manifestations of posttraumatic syndrome are well known to

neurologists and neurosurgeons. These symptoms are not often observed after the more severe penetrating gunshot wounds. So-called blast concussion, with residuals, has only occasionally been seen. Posttraumatic personality disorders and mental deterioration are usually directed to the neuropsychiatric centers.

All cases of posttraumatic syndrome are carefully evaluated and every effort is made to determine the presence of structural damage unless the patient is obviously psychoneurotic. History of loss of consciousness, retrograde and posttraumatic amnesia, bleeding from the orifices and presence of focal or general neurologic signs and symptoms are important. Much objective information can be gained from previous overseas records, such as roentgenographic evidence of fracture, bloody spinal fluid, *etc.* The electro-encephalogram and encephalogram, when positive, furnish tangible data of organic damage. Spinal fluid pressure and chemistry have usually returned to normal when these cases are received two to three months after injury. We have not been impressed with localized headache as evidence of this syndrome.

The use of prostigmine in postconcussion headache and vertigo was recommended by Malone,[6] on the supposition that its vasodilator properties would relieve the intracranial vasospasm. Ten cases were cited, in which relief was obtained. Friedman and Brenner,[3] suggest that a localized vascular sensitivity results from trauma, as demonstrated by histamine studies. We have used prostigmine and histamine in alternate cases in a series of 50 patients. Seven of these treated with prostigmine stated there was temporary relief, lasting usually one to two months, but recurrence was present in all. Histamine desensitization gave negative results throughout. Erythritol tetranitrate was given in 25 additional cases for its vasodilator properties. Slight improvement was seen in one patient. Although it is recognized that disturbances in the vasomotor system are present in some patients of this type, these drugs are no longer routinely administered, as so many secondary factors are present that adequate evaluation is not possible.

Sporadic reports have appeared during the past 20 years, directing attention to the therapeutic value of encephalography in posttraumatic symptoms. The most recent include studies by Maass and Patino,[5] Castaneda,[1] Horrax,[4] and Mayfield.[7] Long-term follow-ups, however, have not appeared. Relief has been explained by the air tension releasing adhesions between the arachnoid and dura. Maass and Patino further recommend this procedure in the prevention of the latter complication in cases of recent head injuries. Davidoff and Dyke,[2] however, feel it of value only in a few selected cases. Penfield,[8] suggested treating these sequelae by spinal or cranial subdural insufflation of air. Early reports were encouraging as to relief from these symptoms.[9] Ross and McNaughton,[12] studied 82 patients from Penfield's Clinic, and concluded that the long-term results were no better than those seen following pneumo-encephalography.

We have now had experience with 125 cases treated by pneumo-encephalography. Only five have mentioned relief over a period of three months observation. We have had no experience with spinal or cranial insufflation An

occasional patient has obtained relief following cranioplasty (syndrome of the trephined).

It would, therefore, appear that there is no specific method of treating posttraumatic states, possibly due to the close association of physiologic and psychologic factors, as suggested by Symonds.[13] We have come more and more to rely upon intelligent handling of the patient, early ambulation, sedation, psychotherapy and well-directed efforts at rehabilitation. This should include a well-organized program with graduated physical and educational facilities.

SUMMARY

We have now used tantalum satisfactorily in the repair of 254 cranial defects. The various methods of preparation and fixation appear to give equally good results. There is no specific medical or surgical treatment for the numerous manifestations of posttraumatic syndrome. Intelligent, judicious management with reassurance, early ambulation, mild sedation, as indicated, and an intensive reconditioning program have given more favorable results than any other method in our experience.

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# THE TECHNIC OF IMMEDIATE RESTORATION OF VASCULAR CONTINUITY AFTER ARTERIAL WOUNDS

## INDICATIONS AND RESULTS

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TORONTO, ONTARIO

WHEN CONFRONTED with the problem of revascularizing the dangerously ischemic limb, one is at once impressed by the unsolved problems in anatomy, physiology and pathology. It is, therefore, essential to define the extent of ischemia affecting the wounded extremity. The dangerously ischemic limb is one which has been deprived of its blood supply to such an extent that vital processes no longer take place and gangrene results. The forerunner of this state is ischemia, and whether the ischemia progresses to recovery or not depends upon the volume of blood the limb receives, the pressure at which it is delivered, the length of time the ischemic state has existed, and the metabolic demands of the limb itself. It is only by a consideration of the general condition of the patient, the time interval, and both the function and appearance of the limb that the degree of ischemia can be determined. The variability of the circulation through the main and collateral channels renders dogmatic anatomic statements worthless. Even though the distal pulses are absent it is reasonably certain that a limb will survive if active movement of the digits is present and the digital skin has some warmth, some sensation, and is not of an unnatural color. If, however, active motion of the digits is no longer present and the digital skin is cold, insensitive, and of an unnatural color, then the limb is dangerously ischemic.

Active surgical interference is to be avoided, when possible, if recovery of the limb is to be expected. In the dangerously ischemic limb, however, operation becomes a matter of some urgency whatever the local arterial lesion. In the absence of arterial spasm and of occlusion of the vessel by extravascular compression, the type of surgical intervention is limited to ligation or some attempt at reëstablishing the circulation.

## SURGICAL PROCEDURES

*Ligation.*—Ligation of the main vessel removes the hazard of further bleeding but does little to improve the blood supply of the limb. Experience has shown us that it is the procedure of choice in certain circumstances:

1. As a life-saving measure.
2. If heparinization is impractical:

The administration of heparin requires qualified supervision including careful nursing and repeated estimations of the clotting time; it is contraindicated in multiple wounds and in wounds involving the cranial, pleural, or abdominal cavities.

3. If the limb has been avascular longer than ten hours:

The survival time of avascular tissue has been investigated by many observers and the general view (with which my own opinion coincides) is, that if warmth to the limb is avoided, skin will survive at least 24 hours, muscle 6 to 10 hours, and nerve perhaps a shorter period.

4. If trauma has been extensive:

Experience with traumatic amputations and with crush injuries would lead one to believe that no attempt at revascularizing a crushed limb should be made until more is known of this pathologic condition.

5. In the upper extremity:

The collateral circulation in the arm is rarely sufficiently damaged to warrant anastomosis of the main vessel.

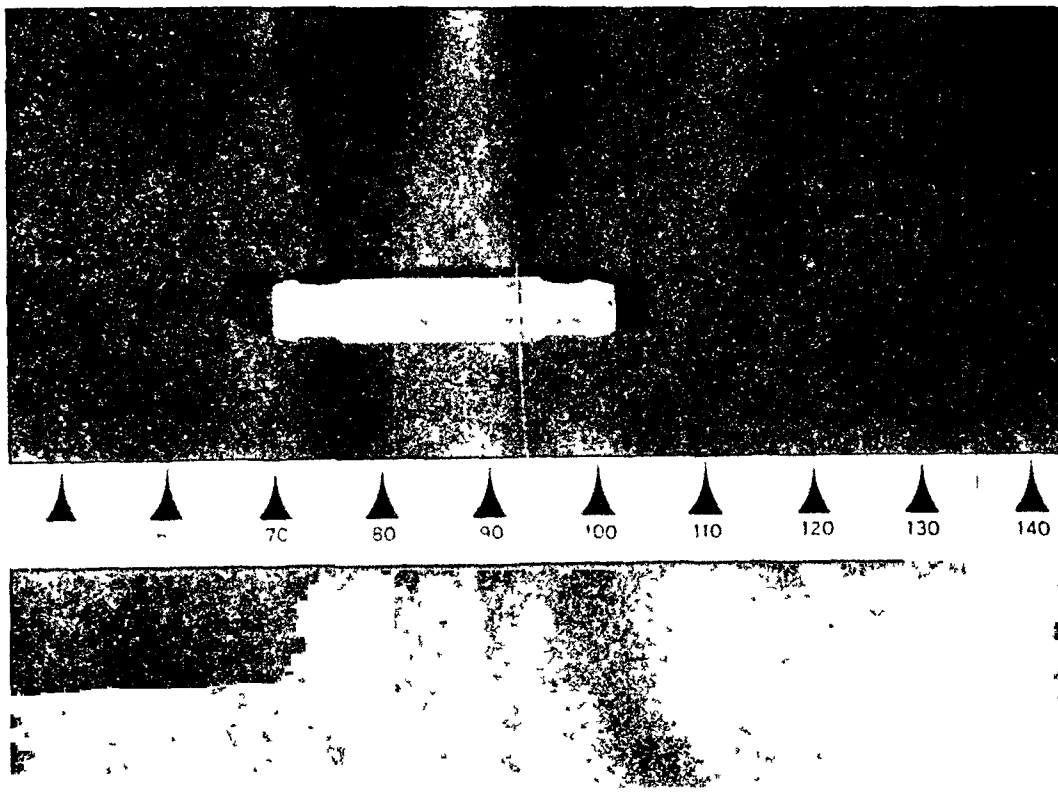



FIG. 1.—Case 15: Plastic tube removed at operation.

*Anastomosis.*—Reëstablishment of the circulation in the dangerously ischemic limb is a practical procedure and may be accomplished by any of the classical methods. Axial anastomosis and suture of the partially divided vessel are ideal but impractical methods which I have not attempted. The insertion of a primary venous graft is a difficult procedure and should be considered an elective operation.

It has been demonstrated experimentally by Murray and Janes,[1] that a glass cannula in the lumen of an artery will remain patent in a heparinized animal, and I have extended this observation to man. Glass tubes are convenient because of their inertness and various lengths and calibers are readily obtainable.

These tubes must, of necessity, be smaller than the lumen of the vessel (since they lie within) and thus stimulate the formation of a collateral circulation. It is preferable to have a small shoulder near each end of the tube and excellent tubes of plastic material are now available (Fig. 1). At the time of operation a wide assortment of tubes should be sterilized since the separation of the ends of the divided vessel is often of surprising extent.

*Technic in Complete Division.*—The approach to the artery should be made carefully in order to preserve the collateral vessels; the ends are identified and cleared of thrombus, bleeding being controlled by tourniquet or bulldog

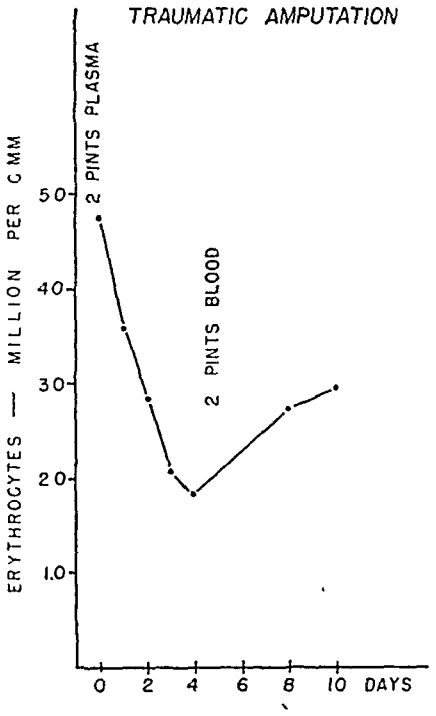



FIG. 2

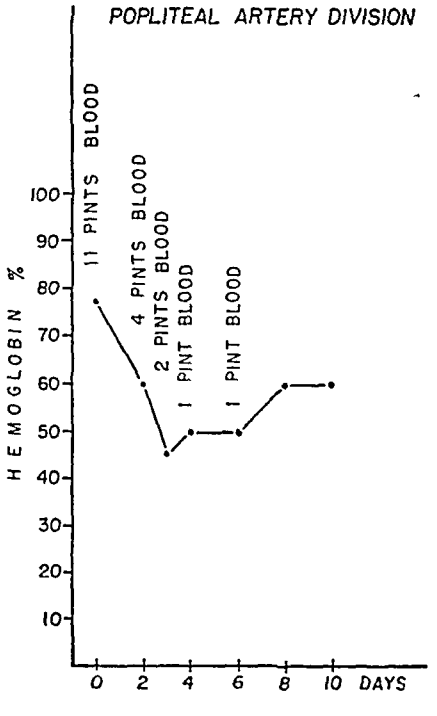



FIG. 3

FIGS. 2 and 3.—Hematocrit readings and blood volume studies in severe wounds.

clamps. The accompanying vein is ligated if damaged and preserved if intact. The distal arterial tree is perfused with heparin solution (1 cc. to 100 cc. saline) and with the intima well visualized, three stay-sutures of fine silk are placed in each open end. The tube is then prepared; it should be as short as possible and fit easily into the arterial lumen; after thorough cleansing it is filled with liquid paraffin, washed out with heparin solution and finally filled with the solution. It is inserted into each end of the divided vessel (care being taken not to strip the intima) and the distal stay-sutures tied to the proximal. Two encircling ligatures (linen or silk) are tied snugly about each shoulder of the tube. Thirty to forty cubic centimeters of heparin solution are injected through a fine needle into the vessel proximal to the tube as the distal clamp is released, the injection continued as the proximal clamp is re-

moved. Immediately following this local or regional heparinization, intravenous heparin solution at the rate of 30 to 40 drops per minute should be commenced. With the reëstablishment of circulation there is considerable venous bleeding and it is well to control this carefully.

*Technic in Incomplete Division and Traumatic Thrombosis.*—In incomplete division the tube is slipped into the lumen after clearing the adventitia and encircling ligatures only are needed. If the lesion is traumatic throm-



FIG. 4.—Case 10: Note length of graft.

bosis, it is wise to place a cannula across the contused segment to add strength to the vessel wall, and to offer a smooth surface to the blood stream. A longitudinal incision is made through the contused area and the thrombus removed: proximal thrombus should be cleared by release of the proximal clamp and great care should be taken to remove distal thrombus with fine forceps or by milking the artery from below. The tube is then inserted across the contused area and encircling ligatures placed at each end.

*Postoperative Care.*—All the usual precautions must be taken to increase collateral circulation; the limb must be kept exposed to avoid warmth (with the accompanying increased metabolic demand), and the remainder of the body

TABLE I—PART 1

| Case No. | Date | Wound to Operation Time | Preoperative Note | Operation |
|---|---|---|---|---|
| 1 | 20/9/44 | 9 hours | Huge perforating wound left forearm compounding both bones; hand cold, mottled and insensitive, forearm tense; general condition fair | Wounds, excised, muscle mass purple in color, median nerve divided, ulnar artery severed at bifurcation, radial intact but in spasm and occluded by a saddle thrombus; removal of this did not change the color of the hand; ulnar artery intubated and the hand became pink and warm and the muscle mass inproved in color. A "captured" Germ and rug used (vetren) |
| 2 | 28/10/44 | 9 hours | Multiple wounds of extremities; bilateral compound femurs; right foot cold, white, insensitive and immobile; general condition poor | Wounds on right leg excised and femoral artery found severed at lower end of Hunter's canal and at inguinal ligament where femur was compound; vessel ligated distally and cannulized at inguinal ligament (above profunda femoris origin). Tobruk splints to both legs, regional and general heparinization |
| 3 | 29/10/44 | 10 hours | Penetrating flesh wound medial aspect right knee; foot cold, insensitive and immobile; general condition fair | Wound excised, femoral artery exposed as it passed into popliteal space and found to be severed, vein intact; artery cannulized, regional and general heparinization foot became pink and warm |
| 4 | 15/11/44 | 6 hours | Penetrating wound right popliteal space; foot cool, insensitive and immobile | Wound excised and artery and vein found divided at level of head of fibula; anterior tibial not identified; either a low popliteal or high posttibial lesion; artery intubated, regional and general heparinization |
| 5 | 21/11/44 | 5 hours | Compound fracture right wrist, huge compound left femur with cold, white, insensitive foot and absent pulsation at ankle; condition poor | Wound excision, traumatic thrombosis femoral and profunda arteries; profunda ligated, femoral intubated after removal of thrombus and foot became pink and warm with pulsation in posttibial artery; regional and general heparinization |
| 6 | 26/11/44 | 6 hours | Large flesh wound above right knee, flesh wound of calf; absent pulsation and inability to move toes; foot warm and slight sensation present; condition fair | Wound excision and femoral artery found severed as it passed through adductor cannal, cannulized but little change noted in foot although palpable pulsation in popliteal artery; regional and general heparinization |
| 7 | 29/11/24 | 3 hours | Large perforating wound left popliteal space without fracture; cold, white, insensitive foot; bleeding requiring tourniquet; condition poor; cell volume 20% | Wound excised, low popliteal division (artery and vein) medial popliteal nerve contused; artery intubated, with foot becoming warm and pink; regional and general heparinization |
| 8 | 5/12/44 | 4 hours | Perforating wound right knee compounding the joint; foot cold, white, insensitive and immobile with absent pulsations at ankle; condition poor | Wound excised and popliteal artery found severed immediately above anterior tibial; artery intubated; regional and general heparinization, sciatic contused but intact; foot warm and pink at conclusion of operation |
| 9 | 7/12/44 | 6 hours | Penetrating wound left thigh, with swelling in Scarpa's triangle rapidly increasing in size, foot warm and pulsations present | Incomplete division of femoral artery probably below profunda, very little bleeding from distal artery; intubation through laceration; regional and general heparinization, foot became warm and pink |
| 10 | 21/1/45 | 2 hours | Multiple wounds right popliteal space and calf and left forearm, no fractures, absent pulsations at ankle; foot cold, mottled, insensitive and immobile; general condition fair | Complete division of popliteal artery and vein and partial division posttibial artery; tube across complete and partial division with knee flexed; foot became warm and pink; regional and general heparinization |

TABLE I—PART 1 (Continued)

| Case No. | Date | Wound to Operation Time | Preoperative Note | Operation |
|---|---|---|---|---|
| 11 | 22/1/45 | 3 hours | Perforating wound right thigh entrance Scarpa's triangle and exit buttock; cold, mottled foot, with absent pulsations and inability to move toes; general condition poor | Wound excised, femoral artery and vein severed and profunda vessels lacerated; femoral artery intubated and foot became warm but not pink, and patient was unable to move toes |
| 12 | 21/2/45 | 16 hours | Large compound left knee joint with cold, white, insensitive, immobile foot; general condition good | Wound excised; traumatic thrombosis of post-tibial artery with severance of anterior tibial; thrombosed segment resected |
| 13 | 1/3/45 | 5 hours | Huge wound compounding wrist and leaving only extensor tendon and overlying skin; hand cold, insensitive and immobile | Wound excised and radial artery ligated, ulnar artery intubated, median and ulnar nerves brought together; regional and general heparinization |
| 14 | 1/3/45 | 6 hours | Penetrating wound right side of neck with a pulsating hematoma gradually enlarging until patient developed laryngeal distress; sensory defect left side (patient left-handed) | Right internal jugular vein and common carotid artery exposed to reveal an arteriovenous fistula; vein resected and artery intubated; regional and general heparinization |
| 15 | 17/4/45 | 10 hours | Large penetrating wound right calf with warm foot and pulsations present | Wound excised and bleeding encountered arising from tear in popliteal artery; artery ligated and 8 hours allowed to elapse, during which time the leg became dangerously ischemic; popliteal was intubated; general and regional heparinization; foot became warm and pink; pulsations returned and patient moved toes freely |

warmed to obtain maximum vasodilation. It has been our experience that elevation of the limb is of considerable importance in order to prevent "muscle edema" (see comment). Pain may be severe and should be relieved by morphine and sleep is essential. If there has been much tissue excision, bleeding is troublesome and repeated estimations of the clotting time are important; if this is above 25 minutes, bleeding will occur; if below 15 minutes, thrombosis takes place in the tube. Every effort should be made to maintain a normal blood pressure and repeated transfusions of heparinized blood may be necessary. The tube may be left in the vessel four to six days without the wall giving way at the site of the encircling ligature.

*Secondary Operation.*—Local anesthesia may be used and heparin should be discontinued an hour or two before operation. With artery clamps on the vessel above and below, the encircling ligatures are divided and the tube removed. The presence or absence of distal pulsation should be noted as well as the degree of ischemia; if pulsation is present or the limb is not dangerously ischemic, simple ligation may be quite safe. If one is in doubt, venous grafting may be performed immediately or it may be reasonable to wait a few hours until the ultimate outcome is certain. If secondary operation is necessary, a venous graft should be inserted, using either the nonsuture method

(Blackmore and Lord,[2] or the end-to-end method which has been successfully employed by Murray.[3]). I have found the vitallium tube method to be less tedious, but prefer the suture method, by which the full caliber of the vein is made available for the blood stream without the reduction in lumen imposed by two thicknesses of vein wall and tube, and a shorter graft may be used under just the right amount of tension. Regional and general heparinization



FIG. 5.—Case 11: This graft was removed

are necessary, and intravenous heparin solution sufficient to maintain a clotting time of 15 to 20 minutes should be continued for at least four days.

*Case Reports.*—Cannulization has been used in 18 cases; three of these were done without the use of heparin and in all thrombosis was almost immediate. In the remaining 15 cases the results are disappointing but not discouraging. As experience has increased, there has been a parallel improvement both in the recognition of cases requiring this operation and in the operative technic. The cases are presented in some detail and a study of the series yields much important information enabling one to approach the problem with a somewhat clearer understanding and perhaps lessen the more formidable obstacles in the path of success.

TABLE I—PART 2

SUMMARY OF DATA OF FIFTEEN PATIENTS UPON WHOM IMMEDIATE RESTORATION OF VASCULAR CONTINUITY AFTER ARTERIAL WOUNDS WAS UNDERTAKEN

| Postoperative Course | Secondary Operation | Secondary Postoperative Course | Result |
|---|---|---|---|
| Hand remained warm and pink, he was able to extend fingers and a radial pulse felt, drug discontinued at 3 days | 25/9/44; Tube removed ulnar artery ligated; further wound excision | 6/10/44: Open reduction fractures with skin graft | 11/7/45: Some improvement ulnar nerve supply after neurolysis, 16/6/45 |
| Leg remained warm to calf; but foot white, cool and insensitive; some ozzing from wounds, (clotting time elevated above 20 minutes) | 30/10/44: Tube removed under local anesthesia and no thrombosis present; end-to-end graft using femoral vein. Blood flow through graft excellent | Heparinized 6 days, then discoumoral; leg remained warm to calf, foot dangerously ischemic; general condition on evacuation 2 weeks later, fair | Stokes-Gritti amputation, with normal blood flow through divided femoral artery |
| Foot remained pink and warm, edema developed and no pulsation felt; able to move toes, only slight hypoalgesia, clotting time kept elevated above 20 minutes and very little ozzing from wound | 31/10/44: Tube removed; no evidence of thrombosis and end-to-end graft—(femoral vein) inserted; at end of operation, foot became white and cold and a dissecting aneurysm was found at distal line; artery opened distally and a tube inserted across distal suture line, foot became warm and pink | 6/11/44: Tube removed, no thrombosis noted; (general heparinization) and artery repair; heparin discontinued after 4 days, foot remained warm and pink but immobile and absent sensation | Walks 200 yards. Ischemic paralysis of sciatic nerve steadily improving. (See Figure 6) |
| Foot remained cool for a few hours and then suddenly became hot but I could not feel any convincing pulsation, clotting time 20 minutes | 17/11/44: The foot gradually became cooler during the last few hours and it was felt thrombosis had occurred despite heparin; wound explored and tube found to have shifted in artery, kinking it with resulting blocking of circulation; tube removed and end-to-venous graft (saphenous) used; distal suture line poor | Foot never did become pink but I felt that it might survive; evacuated 5 days later | Amputation through lower third of femur, with report of infection in calf about graft |

TABLE I—PART 2 (Continued)

| Postoperative Course | Secondary Operation | Secondary Postoperative Course | Result |
|---|---|---|---|
| Foot became cold and white and blood pressure was difficult to keep above 100 despite blood and plasma; swelling and crepitus in thigh noted and heparin discontinued at 24 hours | 23/11/44: High thigh amputation for gas gangrene | 24 hours later patient died in an anuric state. P.M. revealed pale kidneys but nothing further | Died. (See comment) |
| A few hours after operation foot became warm and pink; 8 hours postoperative, patient had a severe collapse, heparin was discontinued and a tourniquet applied to leg; whole blood given quickly, patient responded; very little ozzing on dressings | 29/11/44: Disarticulation through the knee joint | Course uneventful; evacuated 7 days later | Stokes-Gritti amputation. (See comment) |
| Good pulsation obtained in posttibial artery but general condition was poor; blood and plasma given but patient remained *in extremis;* tourniquet applied, with no change in condition and patient died about 12 hours following operation—P.M. demonstrated death due to fat embolism | | | Died. (See comment) |
| Died 8 hours postoperatively despite attempts at resuscitation and tourniquet application. P. M. revealed pulmonary edema and pale kidneys; very little bleeding into the wound | | | Died. (See comment) |
| Postoperatively, there was considerable bleeding from the wound and the clotting time was very difficult to control; the femoral artery was ligated and heparin discontinued | 11/12/44: High thigh amputation for gas gangrene following ligation.<br>13/12/44: Metastic gangrene right leg; disarticulation through knee | Would not respond to resuscitation; massive sulphonamide and penicillin therapy | 14/12/44: Died due to toxemia. (See comment) |
| Foot remained warm and pink, and patient moved toes; slight ozzing from wound | 21/1/45: Tube removed sooner than usual because of its length (knee flexed), no thrombosis on removal; saphenous vein used as a nonsuture graft (see Figure 4); regional and general heparinization; | Toes remained white and immobile and gradually a line of demarcation appeared in mid-tarsal region; 26/1/45: A below-knee amputation per- | Below knee amputation; 2 months later, good stump |

TABLE I—PART 2 (Continued)

| Postoperative Course | Secondary Operation | Secondary Postoperative Course | Result |
|---|---|---|---|
| | toes did not become pink but remained white, skin warm to midtarsal region | formed; the graft examined and found patent. (See comment) | |
| General condition seemed excellent but warmth only persisted to midcalf so that secondary operation was performed earlier than usual | Tube removed (no evidence of thrombosis) and the femoral vein (which had been ligated) was used as a nonsuture graft (see Figure 5). Pulsation obtained distally | Warmth to calf persisted but below this the foot remained cool and the toes immobile; there was no definite line of demarcation but a Stokes-Gritti amputation performed 5/2/45 and venous graft removed. It was thrombosed despite heparinization | Stoked-Gritti amputation |
| General condition remained satisfactory but foot remained dead in appearance | 22/2/45: 24 hours later the posterior tibial artery was intubated and the skin became pink and warm but the foot remained immobile and insensitive | Due to inaccurate clotting time, thrombosis took place in tube and Stokes-Gritti amputation performed 24/2/45 | Stokes-Gritti amputation |
| 24 hours later, fingers pink and warm and patient able to extend fingers; 48 hours later, clotting time dropped to 13 minutes and hand became cold and painful | 6/3/45: Amputation through lower third of forearm | | Amputation through forearm |
| 8 hours later patient developed laryngeal distress due to ozzing in wound (clotting time 38 minutes) | Tracheotomy performed; tube removed and artery ligated | Transient complete hemiplegia gradually improving | 5 months later, sensory defect left hand and slight limp |
| Foot remained warm and pink, and tube left in place 4 days | Tube removed (no thrombosis) and vessels clamped; pulsations disappeared and foot became cold and white; secondary venous graft (suture method) performed with return of pulsations and warm, pink foot | Heparin continued for 4 day; and foot appeared normal with good movement of toes and pulsation in both arteries | 2 months later, patient seen walking with slight limp. (See Figure 7) |

COMMENT

*Blood Loss.*—When an artery is divided, particularly if the division is incomplete, bleeding either into the tissues or to the exterior is considerable; as a protective mechanism, peripheral vasospasm results and in this way the limb may become dangerously ischemic if the blood volume is not quickly restored. To Major J. Dacie and Captain J. Homer the author is indebted for hematocrit readings and blood volume studies on a few of these cases which enable one to make some interesting observations. The estimation of the



FIG. 6.—Case 3: Dotted line represents gradually recovering sensation

hemoglobin is, of course, misleading, since one is dealing with total blood loss, and we have noted that a hemoglobin of 70 to 80% within a few hours of wounding drops to 40 to 50% when the blood volume is restored with fluid other than whole blood (Fig. 2). In Case 8 the patient had lost 80% of his total blood volume prior to operation and recovery could hardly be expected. It is obvious that large amounts of whole blood must be given to increase the supply of oxygen to the ischemic tissue (Fig. 3), and that postoperative bleeding assumes great importance since the loss of 500 cc. in an already exsanguinated patient may prove fatal.

*Heparinization.*—This has been our greatest problem, and the difficulty of administering this drug at a regular rate under Front Line conditions is indeed real. Inaccurate clotting times and irregular rate of flow make the path between thrombosis and bleeding a narrow one and difficult to follow. Pressure dressings impede the collateral circulation, and it is unwise to close the wound tightly. It is dangerous when multiple wounds are present, and if one delays heparin postoperatively to allow clotting to take place in the wounds, thrombosis occurs in the tube. This is a difficult but not insurmountable problem.

*Wound Excision.*—If one has to choose between heparinization or radical excision of a wound then there should be no doubt from the lesson learned in Cases 5 and 9, in which excision was minimized in view of the effects of sub-



FIG 7.—Case 15: Photograph taken in a German prison camp, two months after operation.

sequent heparinization. The wound must first be completely excised before one considers the use of heparin. Fibrin foam has been used on one occasion and it would be advantageous to have a thrombin preparation for local application.

*Revitalization.*—The effects of flooding the circulation with the metabolites of ischemic muscle raises a controversial question. Operations upon the extremities under tourniquet do not as a rule cause systemic effects on the release of the tourniquet; in a limb which had been kept at room temperature for 24 hours no untoward systemic effects were noted (Case 17), nor were any ill effects noted in the autograft of the hand in Case 13. In Case 6, two bottles of whole blood administered simultaneously with the application of the tourni-

quet might have been the deciding factor in resuscitation. The phenomenon of fat embolism (Case 4) in the absence of fracture is little understood.

*Sympathetic Block or Ganglionectomy.*—We have felt that if restoration of the continuity of the main vessel in the dangerously ischemic limb fails to provide skin, muscle and nerve with enough arterial blood for survival then the fate of the limb will not be altered by sympathetic denervation.

*Rigid Tube or Graft.*—The blood flow in the extremity is much greater through a tube than through a venous graft. This is particularly true if the gap is long. In Case 10, a patent venous graft (examined two weeks after insertion) carried only enough blood to maintain viable skin, while with the longer tube in place the patient had moved the toes (Fig. 4). The passive dilatation of the vein wall, however slight, has the effect of lessening the force of the arterial stream; this effect increases with the length of the graft.

*Muscle Edema.*—Every surgeon amputating an ischemic limb has noted that the skin may be warm (even hot) in the calf, although the muscle beneath is ischemic. The muscle is hard, swollen, and pale; it does not contract or bleed and yet bleeding in the subcutaneous tissues may be brisk. Microscopic examination shows considerable separation of the muscle bundles and each fiber is swollen and pale. Muscle demands a greater amount of blood than skin and the presence of any edema within the muscle may create enough tension to prevent blood entering unless it does so with considerable force. This explains the failure in Case 10, and might explain the occasional success of the fascia-splitting operation in the ischemic limb with intact vessel. In Case 10, bleeding was brisk on incision of the subcutaneous tissue of the calf; the muscle beneath was pale, edematous, and it did not bleed; yet when the posterior tibial artery was divided there was a good flow of blood; however, this was a constant stream and not pulsatile as a result of the length and type of graft (Fig. 4).

*Autograft.*—In the upper extremity, whatever the function of a viable hand, it may be preferred to an artificial one. In Case 13, at the end of 48 hours the fingers were warm and the patient could extend them, but on the fourth day thrombosis occurred due to faulty heparinization and the hand was amputated.

## SUMMARY

In the dangerously ischemic limb, reëstablishment of the circulation by artificial anastomosis is practical under conditions where heparinization is possible. The technic of the operation is simple, but postoperative care difficult. The operation has been performed 15 times using heparin; thrombosis does not occur in the tube if the clotting time is kept sufficiently elevated. Careful administration of this anticoagulant with repeated estimations of the clotting time are necessary to ensure success. During the critical period, blood loss must be carefully considered, and the blood pressure maintained by repeated transfusions of whole blood. The limb must be elevated to prevent "muscle edema"; warming the limb is to be avoided and care must be taken with dress-

ings. The tube may be left safely in the vessel up to six days. The second stage of venous graft has been performed six times, the nonsuture method twice, and the suture method four times. Other factors being equal, the success of the graft is in inverse proportion to its length. Following venous transplant, heparinization should be continued for at least four days.

## CONCLUSION

A rigid tube is preferable to a venous graft as a temporary arterial bridge in acute ischemia of the limb. The results of this type of anastomosis have not been impressive and success has been a feat in war surgery in the Forward Area. It is, however, only a beginning in a new field and the application to elective arterial surgery may be of some importance.

The author wishes to acknowledge the helpful criticism and encouragement given him by Brigadier A. E. Porritt, Consulting Surgeon 21 Army Group and Brigadier J. A. MacFarlane, Consulting Surgeon Canadian Army Overseas; and also wishes to thank Prof. J. R. Learmonth for his interest and stimulation. Major F. P. Dewar and my two assistants, Capt. K. E. G. Wilson and Capt. J. B. Lunam, shared the burden of this work which the nursing sisters and orderlies of the Advanced Surgical Center made possible.

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# RECONSTRUCTION OF THE THUMB*

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IN EVALUATING hand injuries, destruction of a thumb is considered to be equivalent to the loss of one-half a hand. To the average individual who must gain his livelihood manually, this injury constitutes a serious handicap.

During a period extending over two years, we have had the opportunity of seeing 26 cases on our service who had a loss of sufficient length of thumb that some type of reconstruction of the digit was considered in order to restore the man's usefulness in a peace-time occupation. Of this group of 26 cases, nine were transferred to other Naval Hospitals for treatment. Out of the remaining 17, three refused operation because they did not feel that their peace-time activities would be hampered too seriously by the deformity. One case lost the entire thumb and its corresponding trapezium, which we felt was too extensive an injury to warrant any type of practical reconstruction. This patient was fitted with a prosthesis, thus, adding some improvement to the efficiency of his hand. The remaining 13 cases requested surgical reconstruction and our experience with this group constitutes the essential theme of this presentation.

## METHODS OF RECONSTRUCTION

In the greater majority of instances, our chief aim has been to establish the opposing mechanism of the thumb against the remaining fingers. The reconstruction of all phalangeal movements, while a desirable ideal, is naturally beyond the scope of practical endeavor in the average replacement. However, four methods of physiologic restoration must be considered: 1. Deepening the thumb web. 2. Pollicization of a remaining partial finger. 3. Replacement with a toe. 4. Lengthening the existing thumb stump.

The operation for deepening the existing web between the thumb stump and the metacarpal of the index finger is the quickest and simplest procedure, and was undertaken on three of our cases. A modified syndactylism operation was carried out plus detachment of the small muscles of the thumb and the first metacarpal. This procedure, of course, gives no length to the thumb, so that the power of opposition is not improved. The chief benefit derived is greater ability to hold an object or tool between the thumb and medial side of the hand.

The second procedure, pollicization of the index finger has been described meticulously by Bunnell,[1] and Gillies and Cuthbert.[2] However, the method should be limited to those cases that present a simultaneous subtotal loss of

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The opinions and views set forth in this article are those of the writer and are not to be considered as reflecting the policies of the Navy Department.

the index finger. Since the thumb is shorter than the index, one can utilize the shortened first finger to advantage. The deliberate partial amputation of a normal index finger to reduce it to a desirable length for a thumb should never be considered. If such a finger were lost during the transfer procedures, further serious damage to the injured hand would result. This complication need not be looked upon with the same degree of seriousness if an already damaged index finger were accidentally lost during some unforeseen operative complication. However, it must be pointed out, that where the indications exist, this reconstructive procedure has considerable merit. We have had no cases in which we felt this operation was indicated.

The third method is that described by Nicoladoni.[3] This operation consists in transplanting a toe (other than the great toe which must not be sacrificed deliberately because of impairing the balance of the foot) to replace the thumb. The toe with its tendons and phalanges are transplanted *in toto* to the thumb by means of a pedicle flap attachment of the toe base to the thumb stump. The procedure, while theoretically possible, can be executed only by prolonged attachment of the hand and foot until a new blood supply is established. Needless to say the position is very irksome to the patient, sufficiently so that we have never had the desire to utilize this operation. One of the former members[4] of our Service, however, states that he did this operation successfully in a small child who had a congenital absence of the thumb. It must be added that children tolerate awkward positions better than adults.

The fourth method is the one with which we have had the greatest experience. Ten thumbs of this series have been reconstructed by this operation.

The procedure consists in constructing first a tube-pedicle flap of skin and subcutaneous fat from a hairless area in the flank. The tube should be made long enough so that there will be adequate mobility of the upper extremity when it is attached to the thumb stump. For longer reconstructions, we have made the customary tube pedicle, leaving both ends attached to the donor area until adequate circulation becomes established in the flap (Fig. 1). Later, the distal end of the tube was attached to the thumb stump. In cases where a shorter flap was needed, a simple flat flap was elevated, leaving only the base attached for blood supply. This flap was then sutured into a tube (Fig. 2-A) at once, and the open end attached to the thumb base at the same operation. In either event, the new union is permitted to grow for three to four weeks before detaching the abdominal origin of the tube. During the interval, however, the blood supply into the new thumb attachment was hastened by either "delaying" the proximal end (Fig. 3-B) of the flap, or by simply clamping it off at intervals with a rubber band. Finally, when one is certain that the new attachment of the tube pedicle will nourish the entire flap, the opposite end is divided from its point of origin and the end sutured over for closure. It should be added, that a tube pedicle of ample length should be provided, since any excess can always be trimmed off at the final revision. Also, after severing the abdominal attachment, the tube should be supported with a splint to prevent angulation and circulatory obstruction at its base.

STABILIZATION

After the flap has healed completely and become well softened, it must then be stabilized to the base of the thumb by some type of support. Various structures have been utilized by different operators for this purpose. Costal cartilage has been unsatisfactory. It has been the experience of most surgeons that the



FIG. 1.—This patient suffered not only a loss of his thumb, but also the index finger. The stump of the first metacarpal was covered with a thin, tender scar which extended upward over the medial side of the midfinger, producing an obvious contracture. In designing the flap to construct this thumb, an extension was made from the medial end of the tube-pedicle to cover over the middle and index finger stump to replace the scarring.

use of bone grafts from the tibia or iliac crest gave rise to an unpredictable amount of absorption when used for this purpose. In searching for a better substitute, it was suggested by Hudack,[5] from our Orthopedic Service, that the twelfth rib be tried. This source was adopted in the first case of our series and has been so satisfactory that it was used in each of the others that followed.

FIG. 2-A

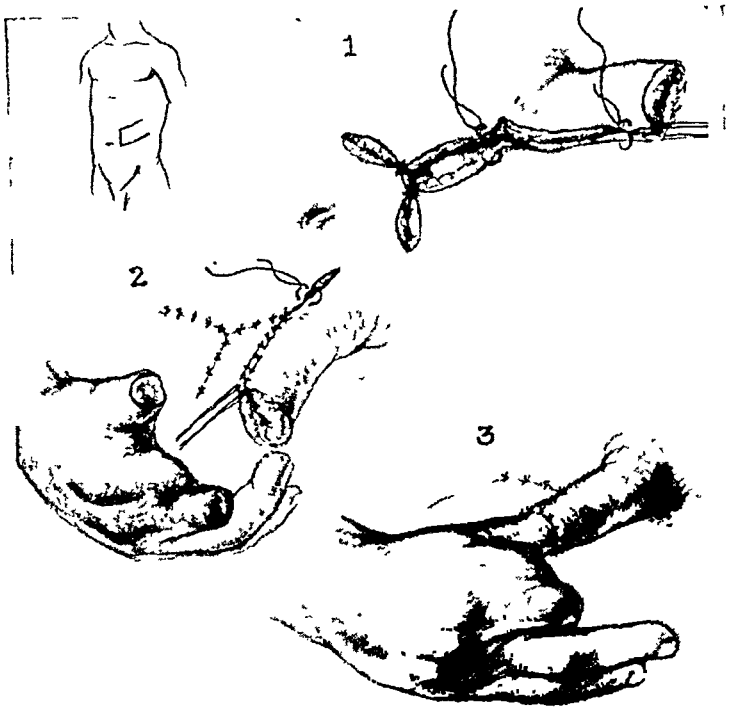



FIG. 2-B





FIG. 2-C



FIG. 2-D

FIG. 2.—(A) Since a new thumb of lesser length was needed here, a direct flap with good blood supply was elevated and detached completely except for its base, at the first operation. The flap was tubed and sutured to the thumb stump at once. This procedure is useful when shorter skin flaps can be utilized, since it saves time. It must be pointed out, however, that it takes experience and judgment in dealing with skin flaps before one can evaluate the risk involved in taking this short cut. (B) shows the patient's hand, and (C) and (D) the result obtained. This patient plans to return to farming, which he states will include milking cows.

FIG. 3-A

FIG. 3-B

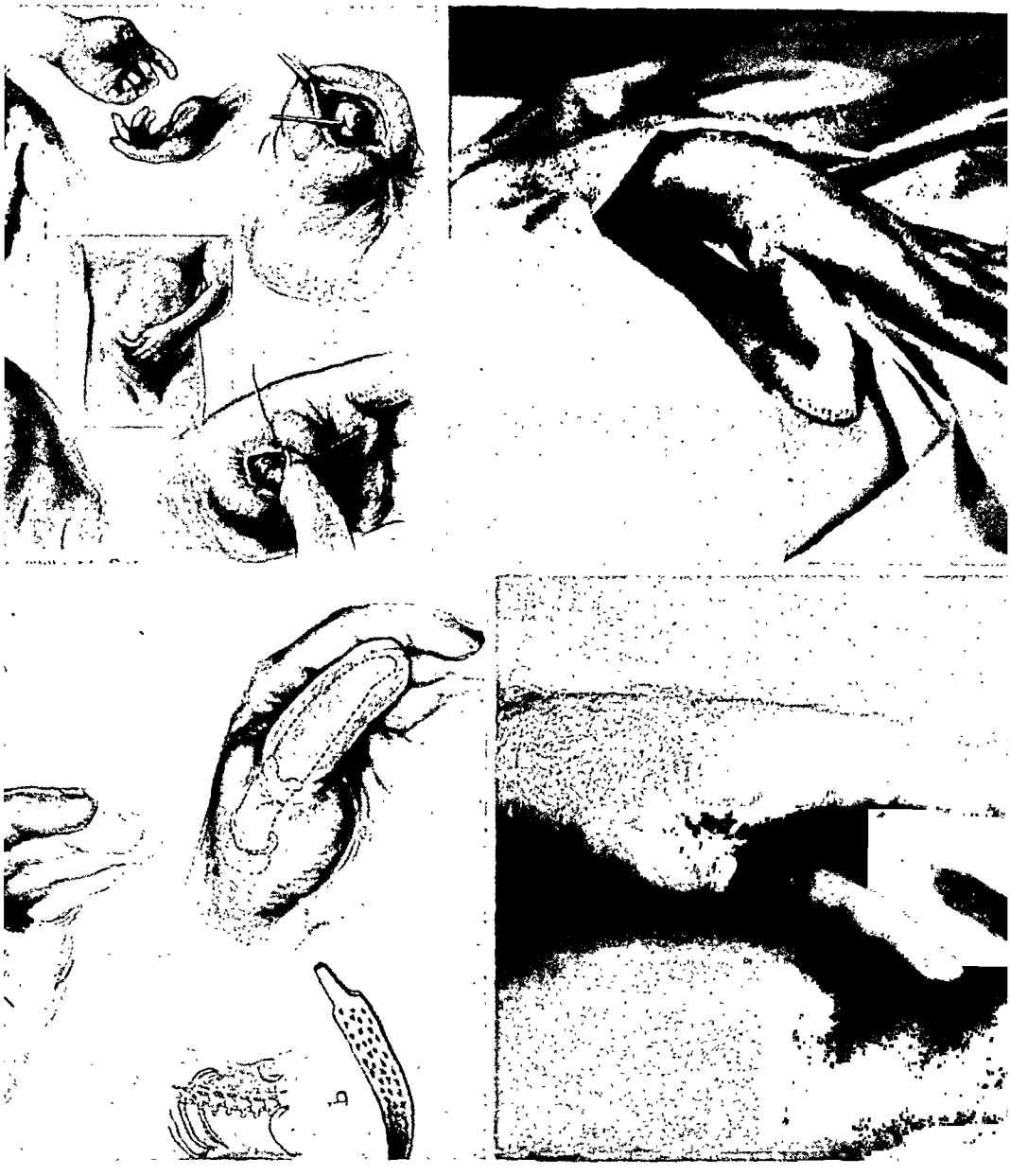


FIG. 3-C

FIG. 3-D

FIG. 3.—(A) This shows a drawing of the pedicle after detachment of its distal end from the abdomen. The scar is excised from the thumb stump and the open end of the tube suture into the defect over the metacarpal. (B) Illustrates the tube attached and subsequent "delay" or partial separation of the flap from the abdomen ten days prior to complete division. "Delaying" the flap hastens establishment of adequate circulation at the thumb attachment. (C) Demonstrates reopening the base of the pedicle after the distal end is well-healed and softened. The metacarpal stump is exposed subperiosteally and the bone graft taken from the left 12th rib. After shaping the graft, the metacarpal stump is drilled and the dowled end of the bone graft swedged into it after first placing the opposite end into the distal portion of the tube. Note the small drill holes placed through the bone graft to encourage early vascularization. The skin incision is then closed and the new thumb supported until bony union occurs. (D) Shows the preoperative view of this case.

Exposure of the twelfth rib is obtained by an incision directly over it. Any of the underlying muscles that cannot be retracted medially are divided. The rib is exposed and removed subperiosteally (Fig. 4-A), following which the wound is closed by layers.

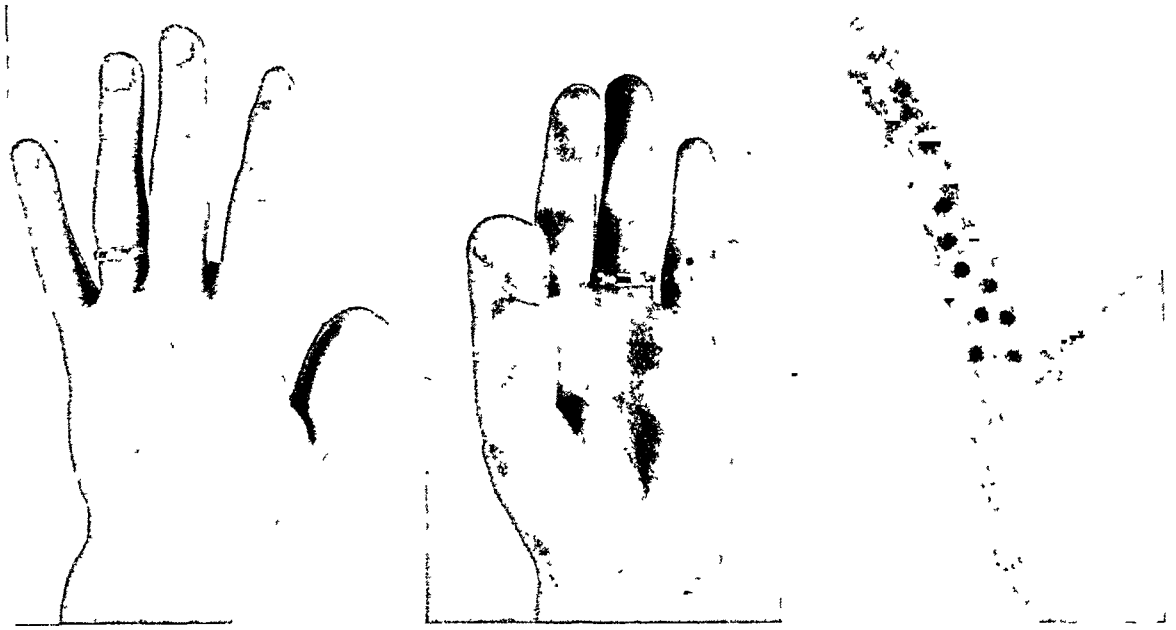
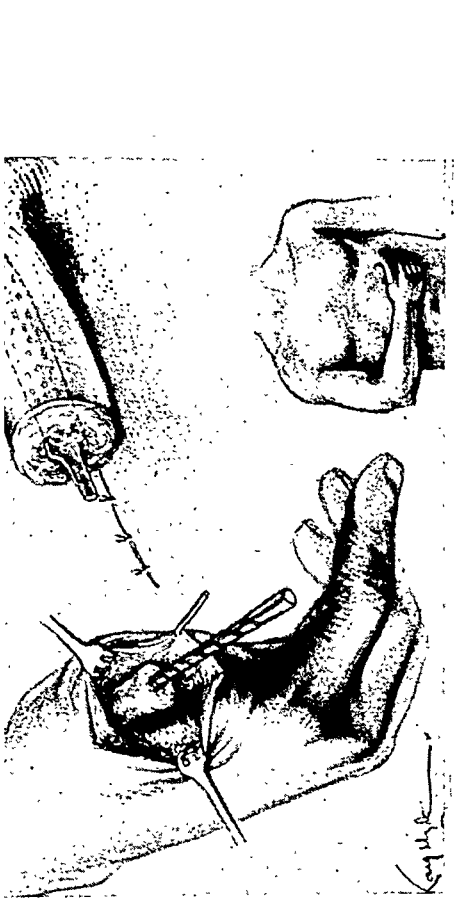


FIG. 3-E FIG. 3-F FIG. 3-G

FIG. 3.—(E) and (F) show the final result of this case. (G) Illustrates an early roentgenographic appearance of the bone graft.

The rib graft is then shaped so as to form a peg in its proximal end (Fig. 3-C). Several small holes are drilled through the bone to encourage more rapid vascularization of its substance.

In one case (Fig. 4-A), we next placed the bone graft into a small tunnel of the tube pedicle while it was still attached to the abdomen. Later, when the pedicle was transferred to the thumb stump, the peg end of the bone graft (Fig. 4-B) was swedged into the base of the remnant of the first metacarpal. However, it seemed too precarious to keep the bone graft in position while the skin flap was healing. Therefore, in the other nine cases we transplanted the bone graft directly into the healed tube after it was well-vascularized to the thumb stump. The technic (Fig. 3-C) consists of exposing the end of the metacarpal through an incision at the base of the pedicle attachment. Retracting the tube to one side, a hole is drilled into the medullary cavity of the metacarpal. A pocket is next made into the center of the tube by blunt dissection with scissors, going from the proximal end toward the distal, but being careful not to traumatize or open the tip. The end of the bone graft is next placed distally into the tube pocket, following which the peg on the proximal end is pushed into the previously-drilled metacarpal hole. The graft remains secure by friction and no other fixation is necessary. The skin incision is next sutured and the reconstructed thumb supported with either a splint or plaster of paris encasement.









After placement of the bone graft, it has been observed that clinical union occurs in two to three months and roentgenographic evidence of complete healing is seen in six months. After clinical union takes place, the thumb is finally trimmed of any excess skin and subcutaneous fat. Occasionally, it has been necessary to trim off some of the bone graft tip to give a more desirable length. When this was done, it has been gratifying to observe the profuse bleeding that came from the cut end of the transplanted bone. Except for bathing, we have kept these newly constructed thumbs supported with an aluminum splint until evidence of complete bony union was visualized (Fig. 4-E).

## COMPLICATIONS

Three types of complications were encountered in our series of ten cases. The most persistent was noted in eight. This consisted in a break-down of the end of the tube pedicle flap after it had been divided from its abdominal origin, and is a complication that has been encountered by other plastic surgeons, both in this country and abroad.[6, 7] In each case, at the time of sectioning the tube, an excellent blood supply was noted. After closing the open end by suture, primary healing always occurred. But 10 to 18 days later, a cyanosis and subsequent gangrene developed along the suture line and then spread out over the tip. It seemed at first that this was probably due to passive congestion, but pressure dressings over the tip did not produce material change in any case. Following the necrotic process, an ulcer developed over the tip that would not heal primarily nor would a thin split-skin graft grow on the granulating base. Chemotherapy was of no aid. Ultimately, the ulcer was excised and the flap end resutured. In some cases the process repeated itself two or three times before permanent primary healing occurred.

The second complication was that of infection and necrosis of the bone graft. This occurred in two cases. In each, the graft was removed when it was evident that sequestration was inevitable. After permitting the tube pedicle to heal, the opposite twelfth rib was transplanted and grew successfully. Consequently, we feel that this complication was probably due to a technical error at the time of carrying out the primary bone graft.

The third complication was entirely accidental. This patient played water basket-ball against instructions three months after his bone graft had been

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FIG. 4.—(A) Explains the operative technic for removing the 12th rib. In this case the bone graft was placed first into the tube pedicle while it was still attached to the abdomen at each end. Later, (B), the distal end of the tube was attached to the thumb stump and at the same time the base of the bone graft swedged into the metacarpal. This order of procedure has been abolished because of the difficulty in holding the hand in position without accidentally pulling the bone graft out from its new bed. The procedure described under Figure 3 is simpler and associated with less hazard.

Figures 4-C and 4-D illustrate the case involved. Figure 4-E shows the roentgenogram of the bone graft 16 months after transplantation. Good bony union is noted. (This is the same case that suffered a greenstick fracture at the base three months before, when injured while playing water basket-ball.) This patient plans to return to a civil occupation as a mathematics instructor in a University. We feel confident that the restoration will enable him to hold a piece of chalk.

performed. During this athletic escapade, the tip of the new thumb was accidentally struck with the basket-ball, producing a greenstick fracture near its base. The fracture was reduced and splinted, and it was very gratifying to note that complete union of the bone graft occurred in approximately two months.

FIG. 5-A FIG. 5-B FIG. 5-C

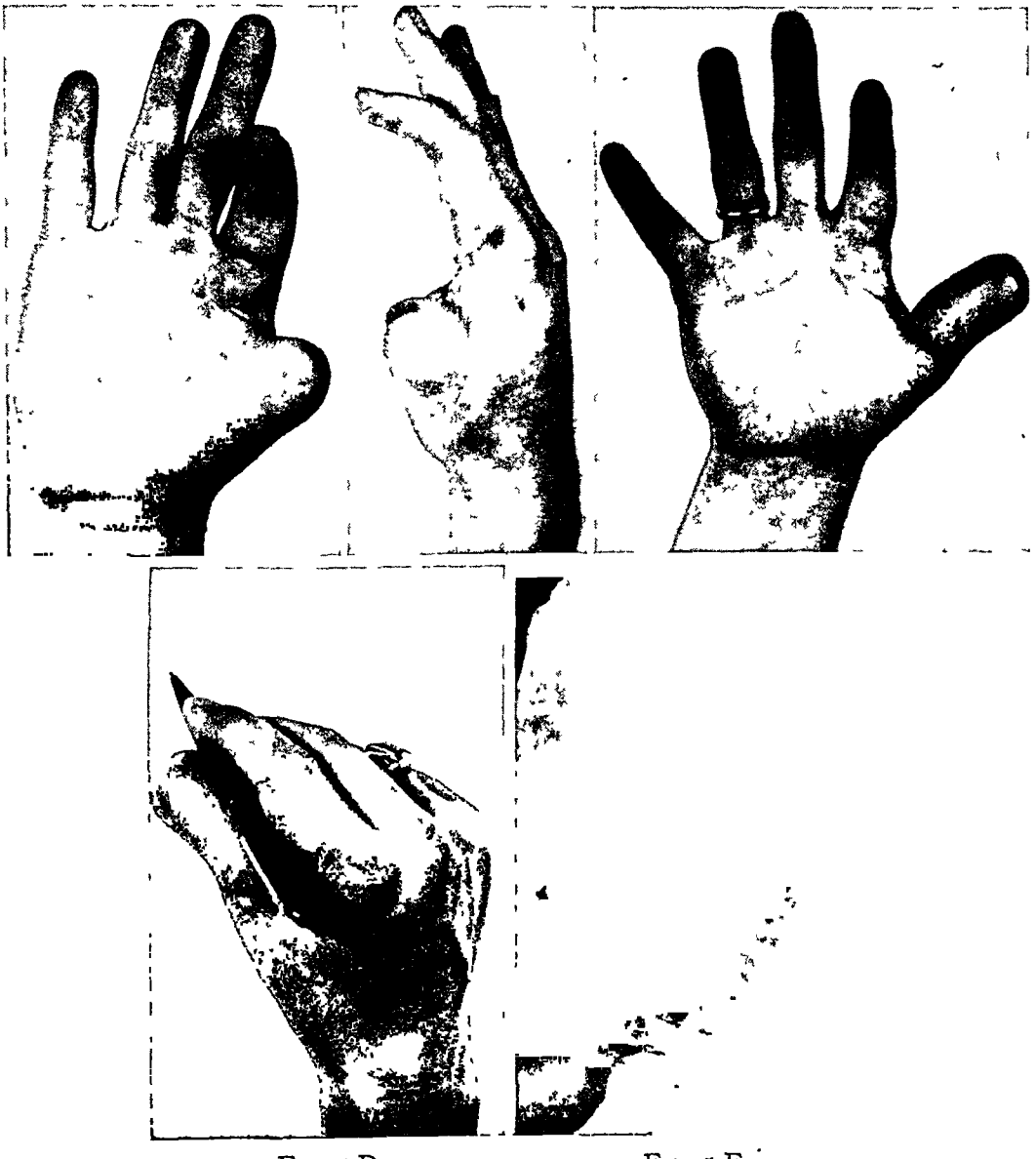


FIG. 5-D FIG. 5-E

FIG. 5.—(A) and (B) Show a partial loss of the thumb complicated by a healed compound fracture of the index finger. This latter injury limited complete flexion of this digit very markedly. The thumb was reconstructed by the "short method" described in Figure 2. The result is shown in Figures (C) and (D). Figure (E) shows the bone graft three months after transplantation.

## SUMMARY

In a series of ten cases of reconstruction of the thumb, utilization of the twelfth rib for stabilization has given very satisfactory results in our hands.

FIG. 6-A



FIG. 6-B





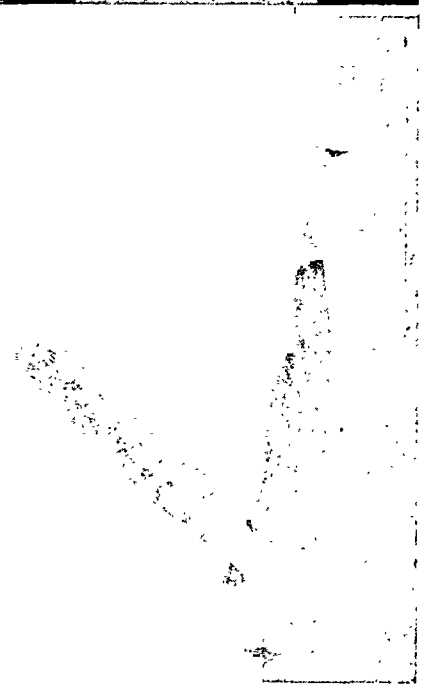


FIG. 6-C

FIG. 6-D

FIG. 6.—(A) This case is included because of the extensive loss. (D) Shows the roentgenogram of this patient, demonstrating a complete absence of the metacarpal down to the trapezium (greater multangular). A new digit was constructed, Figs. (B) and (C), with a good result considering the magnitude of the deformity. The roentgenogram (D), taken four months after transfer, shows how the base of the bone graft was swedged into the trapezium. Some motion was obtained from the residue of the small muscle group at the base of the thumb. This is an ideal case in which to consider pollicization of the index finger if a coexisting partial amputation of the index occurs simultaneously. However, it does not seem good judgment to hazard transfer of an uninjured index finger. (See text.)

While this method of restoration does not provide phalangeal joint activity, there is sufficient range of motion at the metacarpocarpal point to allow for good opposition against the other remaining fingers. This simple action does much to restore the usefulness of the hand.

All types of sensation except that of stereognosis develop in the transplanted skin flap. The speed with which these sensory recoveries develop followed no definite rate. The time varied with different individuals from six months, to one case which still does not have complete return after two years.

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# CERVICAL RIB: THE ROLE OF THE CLAVICLE IN OCCLUSION OF THE SUBCLAVIAN ARTERY

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THIS REPORT includes the study of a series of cases of cervical rib in which it was found that the subclavian artery was intermittently occluded by mechanical pressure between the clavicle and the aberrant rib. In one of these cases, the vascular disturbances were sufficiently severe to lead to gangrene of three digits of the right hand. Scaleniotomy alone failed to relieve the condition which was corrected only by excision of the offending rib.

Jones[7] pointed out that while snakes have cervical and lumbar ribs, lizards do not. His theory is essentially that the outgrowth of mesenchymal and neurogenic structures to the limb buds shear off the soft uncalcified anlages of the neck ribs during embryologic development. If the upper extremity descends too fast and too far, it shears off the upper thoracic ribs as well (Fig. 8). If it descends too slowly, the seventh cervical rib is permitted to develop. The roentgenographic findings in two of our cases tend to confirm Jones's theory. Figure 7 shows a deep indentation made in the cervical rib by the subclavian artery. The impression one gets is that during the embryonic life of this individual the shoulder descent stopped as the neurovascular structures were cutting through this rib anlage. The same general principle applies to the aberrant first thoracic rib in Figure 8, except that in this case the neurovascular structures had proceeded caudad too far and were in the process of shearing off the highest thoracic rib when the descent was halted. The head of this rib had been levered cephalad from the pressure on its distal end.

Jones believed that vascular symptoms result from irritation of the sympathetic nerve fibers in the lowest trunk of the brachial plexus. Todd[13] produced further evidence to support this theory which was later elaborated upon by Telford,[12] who believed that only those cases of cervical rib that have some abnormality in the distribution of sympathetic fibers have symptoms. He has shown that in the normal individual these sympathetic fibers to the blood vessels join the roots of the brachial plexus and are mixed thoroughly with the myelinated nerve fibers by the time these nerve trunks cross the cervical rib. In approximately one individual in eight, the sympathetic nerve fibers to the blood vessels form a special bundle situated just below the lowest trunk of the brachial plexus. This bundle of unmyelinated nerve fibers is in a position to be irritated by an abnormal cervical rib since it crosses the rib as an entity before its fibers mingle with those of the larger nerve trunks. It is in this type of case

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that the vascular symptoms are believed to occur. Telford[12] does not believe that gangrene could be caused by pressure on the artery alone. He has demonstrated that occlusion of the main artery to the arm, when it occurs, begins beyond the lower border of the major pectoral muscle. It is at this site that the sympathetic nerve fibers surrounding the blood vessel itself come to an end and the unmyelinated nerve fibers from the brachial plexus previously referred to begin to take over. Irritation to these sympathetic fibers would set up a spasm in the blood vessels. Such vascular disturbance may be brought about by irritation of the sympathetic fibers from friction or pressure.

Factors which lead to abnormally intimate relationship of the brachial plexus and cervical or first rib are: (1) anatomic position of the lower nerve trunk and rib as previously described; and (2) abnormally rapid descent of the shoulder girdle from either developmental causes, abnormal weight-bearing, or from weak muscles. If depression of the shoulder is great, the sympathetic nerve fibers may be completely destroyed and no vascular spasm will result. Telford[12] sets forth an interesting theory to explain the thrombosis occurring in such cases. It is his belief that the spasm set up interferes with the vasa vasorum. The nutrition of the endothelium is thereby disturbed leading to thrombosis.

Blair[3] also believes that the vascular symptoms in patients with cervical ribs are produced by vasospasm. He studied a case of cervical rib with vascular symptoms who subsequently died. Microscopic examination of the lowest root of the brachial plexus revealed a distinct bundle of unmyelinated sympathetic fibers situated at a low level in direct contact with the aberrant rib. He believed that stimulation of these sympathetic fibers by friction over the cervical rib had produced the vascular disturbances.

Adson and Coffey[1] focused attention on the scalenus anticus muscle as an important factor in production of symptoms in cases with cervical rib. They believed that a great deal of the disturbance produced was due to pressure exerted on the subclavian artery and brachial plexus by the scalenus anticus muscle in front and by the cervical rib from behind. They introduced a diagnostic maneuver which determines the degree of scalenus anticus pressure. This test, now known as the "Adson maneuver," consists of putting the scalenus anticus muscle under tension by having the patient turn the head toward the affected side, throw the head back, and take a deep breath. The test is positive if the radial pulse is diminished or shut off. They recommended section of the scalenus anticus muscle with or without removal of the cervical rib for correction of this condition.

Ochsner, Gage and DeBakey[9] further incriminated the scalenus anticus muscle by showing that it could do harm to the brachial plexus even in the absence of a cervical rib. One of the theories they offer to explain the mechanism whereby symptoms are produced is essentially that of Todd, previously referred to. This theory is based on the fact that the thoracic cage and shoulder girdle descend to a lower level as one grows older. This drop is brought about by two factors; the pull of gravity; and the tension of the rectus abdom-

inis muscle. If the descent of the thoracic cage is held up for some reason and the shoulder girdle continues to drop, the nerves and arteries to the arm become unduly stretched over a cervical rib or a high first rib. When the lower roots of the brachial plexus become irritated by a cervical or high first rib spasm of the scalene muscle results, elevating the offending rib further, and so a vicious cycle is set up.

They reported six cases of scalenus anticus syndrome, all women. Four had symptoms on the right and two on the left, and all had tenderness on pressure over the scalenus anticus muscle. The diagnosis was worked out on a scientific basis. This syndrome must be differentiated from: (1) supraspinatus injury; (2) subarachnoid tumor; (3) cervicodorsal sympathalgia; and (4) Raynaud's disease. To this list may be added cervical arthritis; brachial plexus neuritis; and a slipped intervertebral cervical disk. They have obtained good results in such cases by resection and removal of a portion of the scalenus anticus muscle close to its attachment to the first rib.

Hansson[6] suggested a series of exercise for relief of symptoms. The aim of these exercises is to strengthen the trapezius and levator scapulae group of muscles in order to elevate the shoulder girdle. We have found these exercises beneficial in cases of cervical rib with minimal symptoms.

Craig and Knepper[4] recommended removal of a portion of the cervical rib, as well as section of the scalenus anticus. Patterson[10] divides the scalenus anticus and, in addition, the scalenus medius and removes a portion of the cervical rib.

Judovich[8] mentions that a narrowing of the costoclavicular space may produce symptoms from vascular compression. Wright[15] believes that the large nerves and blood vessels to the arm may become pinched at times between the first rib and clavicle. Aynesworth[2] also lists the possibility of obstruction of the subclavian artery between the clavicle and a cervical or first rib. He also believes that trauma to the subclavian artery may result from excessive movement of the shoulder.

### MECHANICS

Cervical rib occurs more frequently on the left, but symptoms are usually on the right because of the greater use of the right arm. Similar symptoms may be produced when no cervical rib is present. Symptoms are usually a result of injury to the subclavian artery or the brachial plexus nerves. Injury to these structures may be produced as a result of either (1) pressure; (2) stretching; or (3) friction. Pressure symptoms are produced from a pinching between two structures, one behind and one in front. The structures producing pressure from the back may be: (1) cervical rib; (2) a fibrous band representing a cervical rib; or (3) scalenus medius and posticus muscles. The pressure from in front may be from the scalenus anticus muscle or the clavicle.

Stretching of the nerves and arteries are produced by a cervical rib or a highly placed first rib which acts as a pulley over which these structures run. Tension may be increased distally by a depression of the shoulder; proximally

by a low origin of the roots of the brachial plexus. Tension from a high first rib or cervical rib may be accentuated by an elevation of the thoracic cage in general as a result of excessive muscular development resulting from strenuous exercises. The strain of military life involves the use of the extraordinary muscles of respiration, particularly the sternomastoid and the scalene muscles, resulting in an elevation of the thoracic cage.

Ochsner[9] believes that the first rib may be elevated by spasm of the scalene muscles associated with either myositis or brachial plexus neuritis. Depression of the shoulder is an important factor in females and older males with weakness of the musculature. It may also be present in younger men from excessive weight-bearing, such as carrying a pack or from faulty development.

## SURGICAL ANATOMY

The surgical anatomy of cervical rib is essentially that of the posterior triangle of the neck. The posterior triangle curves obliquely around the lateral aspect of the neck. It is bound in front by the sternomastoid, behind by the trapezius, while its base is formed by the middle third of the clavicle. Its floor is formed from above downward by the splenius capitis, levator scapulae, scalenus medius, and posticus muscles, the first rib and the first digitation of the serratus magnus. The scalenus anticus muscle does not form a part of the posterior triangle since it is directly behind the clavicular portion of the sternomastoid muscle. The contents of the posterior triangle are: (1) arteries—the third part of the subclavian above which is the transverse cervical and supracapular; (2) veins—the subclavian and external jugular; and (3) nerves—the brachial plexus.

The third part of the subclavian artery lies in the base of the posterior triangle about which is the suprascapular and transverse cervical arteries. Above these again is the omohyoid muscle. The subclavian artery is divided into three parts by the scalenus anticus muscle. The first part is medial to the muscle, the second part directly behind, and the third part is lateral. The subclavian vein is below and in front of its artery with the scalenus anticus muscle lying between. The phrenic nerve passes downward in front of the scalenus anticus muscle toward the medial border. The cervical pleura is directly below and behind the first and second parts of the subclavian artery. It extends higher in the neck in the case of persons with cervical rib.[10] An important relationship to the first part of the subclavian artery on the left side is the thoracic duct which arches down in front of it in order to end at the junction of the internal jugular and subclavian veins. The first rib is below the third part of the subclavian artery, while the external jugular vein crosses in front. Posteriorly, it is in relation to the median and posterior scalene muscles with the lowest trunk of the brachial plexus intervening.

A medially placed cervical rib may be directly behind the scalenus anticus muscle with the large nerves and arteries intervening. This type of case would give a positive Adson test and would be expected to be relieved by a scaleniotomy alone. A laterally placed cervical rib behind the third portion of the

subclavian artery would be more liable to produce symptoms from pressure on the subclavian artery between the abnormal rib and the clavicle. Such a case would show reduction or absence of radial pulse in the attention position and would require removal of the cervical rib in addition to scaleniotomy.

## CLINICAL ASPECTS

Symptoms occur in two general types: (1) young muscular males; and (2) older debilitated males or females. Only 55 per cent of cervical ribs give symptoms and only about 11 per cent require surgery.

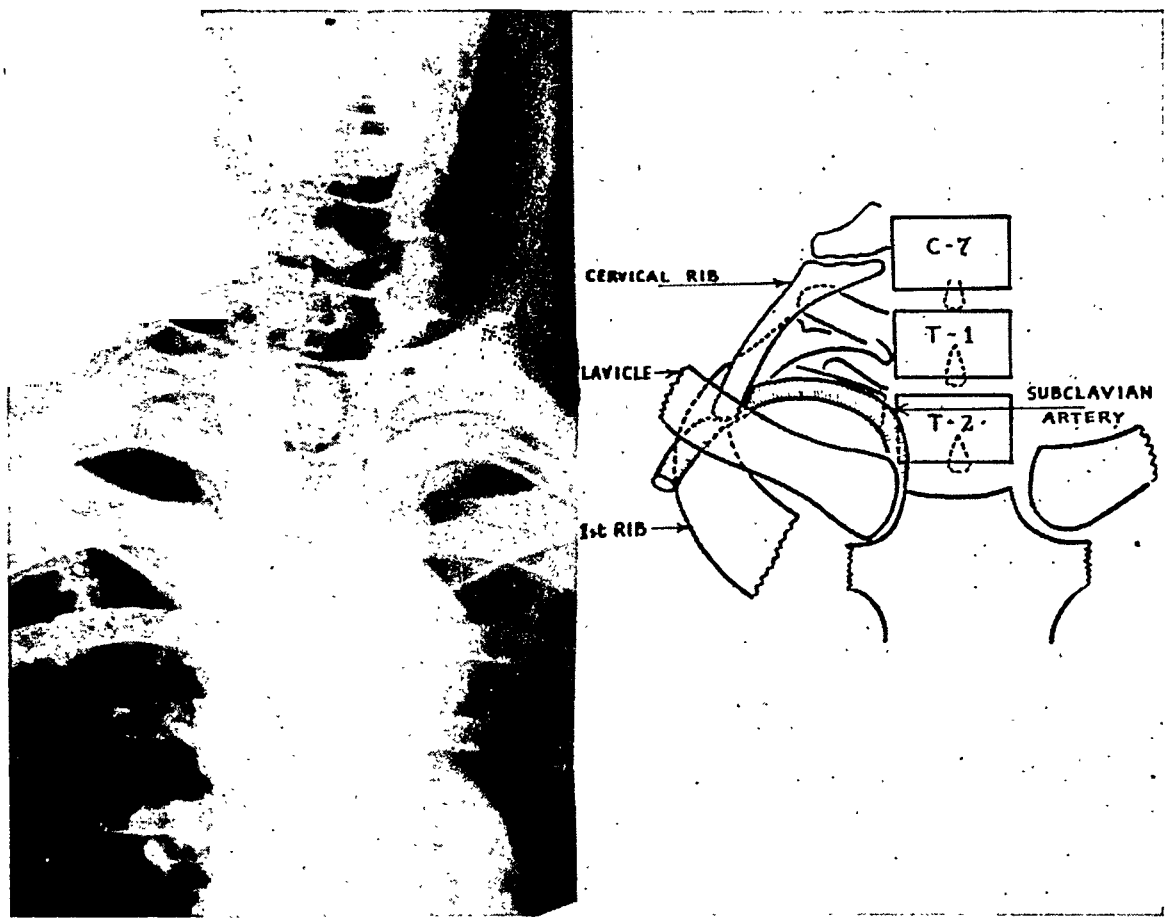



FIG. 1.—This illustrates the manner in which the subclavian artery was occluded between the cervical rib and clavicle. This rib produced vascular symptoms only. (Case 1.)

*Symptoms* are either (1) neurologic or (2) vascular. Neurologic symptoms may be due to pressure, stretching, or friction. Neurologic pain is of a sharp lancinating or boring type. It may be located in the scapular region with radiation down the arm and at times up the side of the neck. Pain is worse toward the end of the day, especially in females, and is aggravated by certain types of work which depresses the shoulder, such as weight-bearing or sweeping. One of our patients developed symptoms when he was painting low shelves; swinging the arms in marching caused symptoms in the same man. Anesthesia, paresthesia, formication, burning, tingling, or numbness may be present. Physical examination may reveal atrophy of muscles supplied by the ulnar nerve, and occasionally those supplied by the median. Trophic disturb-

ance may be present, such as dryness of the skin, loss of hair, loss of nails, but actual gangrene is rarely found.

Circulatory symptoms include blanching, numbness, tingling, or coldness. These occur during the carrying of a pack or gun, assuming the position of attention for long periods or while asleep. One case developed symptoms while sitting in a picture show.

The chief *diagnostic* problem is to determine whether or not a cervical rib known to exist, roentgenographically, is responsible for presenting symptoms.



FIG. 2.—After removal of the greater part of the offending rib. (Case 1.)

A history of scapular pain radiating down the arm, worse on depression of the shoulder, is a good indication of neurologic pressure. Several tests have been worked out which are helpful in determining nature and degree of disturbance. One of these, the "Adson maneuver," previously referred to, supposedly puts the scalenus anticus muscle under tension, resulting in pressure on the subclavian artery and brachial plexus nerves. The test is positive when the pulse is shut off or reduced in volume, as determined by palpation, blood pressure or oscillometric readings.

In the cases herewith presented it was found that with laterally placed ribs the pulse may be obliterated by counter pressure from the clavicle when the

shoulders are thrown back, as in the position of attention. In such cases, the cervical rib can often be felt in the base of the posterior triangle of the neck. The subclavian artery may be palpated in front of this and the clavicle in front of this again. If the patient is then asked to throw the shoulders back, the artery may be occluded at this point. Under such circumstances one can feel the subclavian artery pulsate distal to the scalenus anticus muscle, and so incriminate the clavicle as the subject of counter pressure.

The *treatment* may be medical or surgical. Medical treatment, which aims at elevation of the shoulder girdle by exercises designed to strengthen the

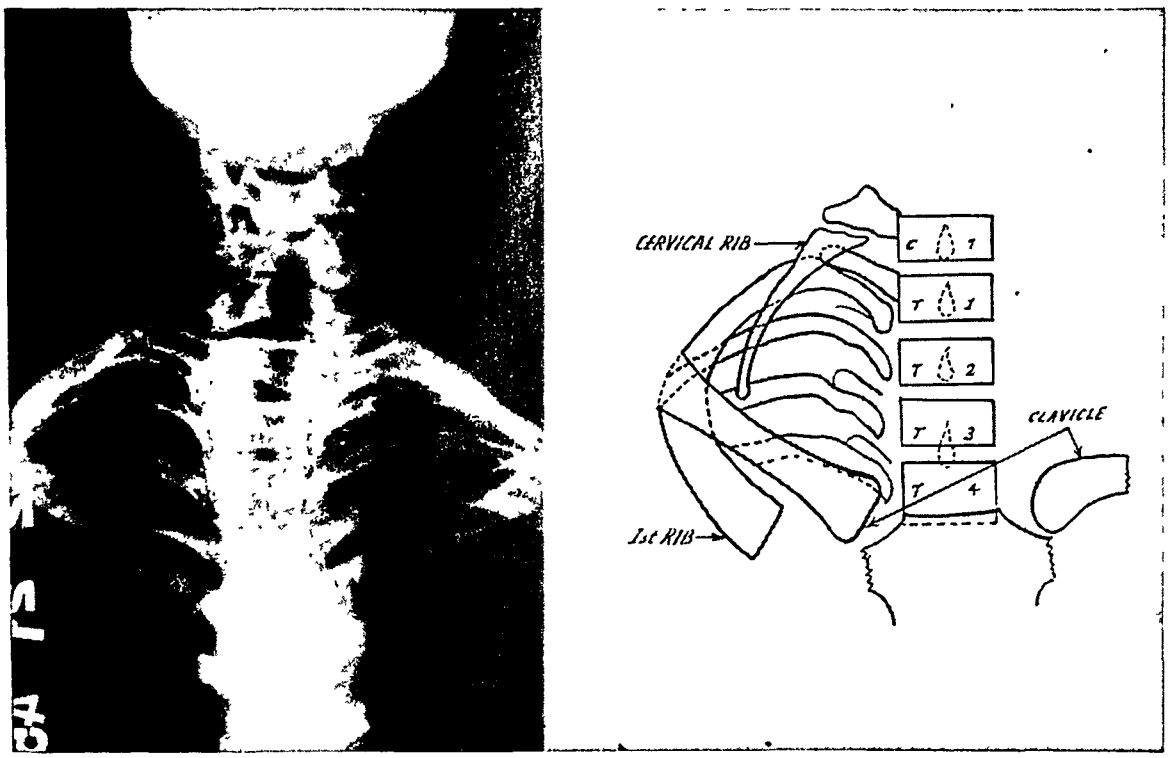



FIG. 3.—Symptoms in this case were neurologic and vascular. The lower trunks of the brachial plexus were stretched over the sharp upper margin of this narrow rib. The subclavian artery was occluded between the slightly expanded tip and the clavicle. (Case 2.)

trapezius and levator scapulae muscles, may be tried in mild cases. One exercise recommended by Hansson[6] consists of clasping the two hands together and pulling straight back at the same time as the shoulders are elevated. The patient is taught not to throw the shoulders back or to carry heavy weights. Posture should be that which is considered as good posture in general, except that the chin should not be pulled in but allowed to go forward and slightly elevated to relax the scalene muscles. The shoulders may be squared-off but should not be thrown back. If symptoms tend to develop at night, the patient should be taught to lie on his side with both shoulders forward, or if he lies on his back, he should have an extra pillow under the affected shoulder and the head flexed forward. The soldier is usually placed on duty, with carrying of heavy packs forbidden; also the strenuous exercises should not be indulged in since the muscles of extraordinary respiration tend to elevate the thoracic cage.

*Surgical treatment* consists of division of the scalenus anticus muscle with or without removal of the surgical rib. The aim of the treatment should be the relief of pressure or tension on the arteries and nerves. This is accomplished by cutting the scalenus anticus muscle to allow the subclavian artery and large nerves to fall forward and to a lower level. If there is still tension, then the cervical rib must be removed. Ochsner[9] believes that division of the scalene muscle permits the first rib to drop to a lower level. This drop, however, is probably hindered by attachments of other muscles, such as the scalenus medicus and posticus to the first rib and also the fact that the first rib is fixed to the sternum which, in turn, is held up by the sternocleidomastoid.

## SURGICAL TECHNIC

Besides the brachial plexus and the subclavian artery, there are three other important structures to guard against injuring. They are: (1) the phrenic nerve; (2) the cervical pleura; and (3) the thoracic duct on the left or occasionally an aberrant lymphatic duct on the right. Donald and Morton[5] reported a case in which the thoracic duct was accidentally cut and ligated, with recovery. In cases with bilateral symptoms, only one side should be done at a time since Spurling[11] has shown that temporary paralysis of the diaphragm develops regardless of the care exercised in handling the phrenic nerve. The function of the diaphragm returns in about six weeks.

Intratracheal gas, oxygen and ether anesthesia is the best since positive pressure can be given in case the pleura is nicked. Cotton suture technic is used throughout. An anterior approach similar to that recommended by Adson[1] is used. An incision is made 2 cm. above and parallel to the inner half of the clavicle beginning at the sternal attachment of the sternocleidomastoid and extending laterally for a distance of 6 cm. The skin and platysma are incised and the clavicular portion of the sternomastoid is cut across. The external jugular is cut and ligated. The transverse cervical and suprascapular vessels and omohyoid muscle may be cut. The deep fascia should be cut across exposing the following structures from within outwards: (1) the carotid sheath; (2) the scalenus anticus muscle, running across which is the phrenic nerve; and (3) the third portion of the subclavian artery, behind which is the lower trunks of the brachial plexus. The carotid sheath is then retracted medially together with the phrenic nerve. The scalenus anticus muscle is dissected free from surrounding structures for a distance of several centimeters, care being exercised along its medial border to avoid injury to the thoracic duct. A curved hemostat is then placed underneath the muscle close to its insertion into the first rib. The muscle fibers are then cut across, a few at a time, with a sharp knife. Bleeding is controlled by figure-of-eight sutures of fine cotton, which are placed in the muscle before its posterior sheath is cut in order to avoid the difficulty of trying to stop the bleeding after the muscle retracts. One must be sure to cut all the fibers of the muscle and its posterior sheath. If any of the posterior sheath remains, the muscle cannot retract, and its ends may reunite. After the scalenus anticus is cut, the subclavian artery will usually fall

forward over the distal end of the muscle. The proximal end of the cut muscle will retract for a distance of several centimeters. Ochsner believes a section of the muscle should be removed.

The procedure up to this point is considered adequate for cases in which symptoms are due to the scalenus anticus muscle alone. For those cases in which the pressure is between the cervical rib and the clavicle, or the brachial plexus appears to be under tension, a portion of the cervical rib must be removed. The subclavian artery is then separated from the brachial plexus

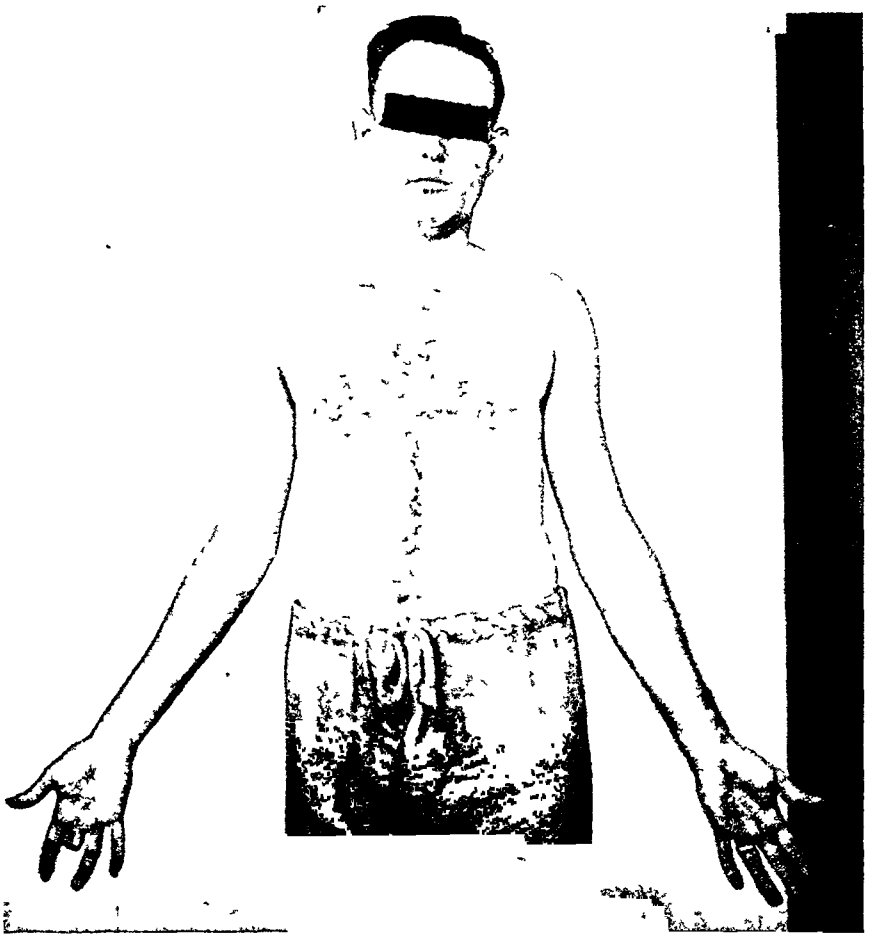


FIG. 4.—This is a case of right-sided cervical rib with costo-clavicular vascular compression. Note deviation of the head to the left to compensate for depression of the right shoulder, general atrophy of the right arm, and absence of the right third finger. (Case 1.)

trunks and freely mobilized. It is retracted downward in its second and third parts, and the lower trunks of the brachial plexus are gently retracted upward exposing the cervical rib. The rib is then separated from the cervical pleura and from the soft tissues beneath it. The rib is then cut across at about its middle and the anterior portion is removed. The posterior portion is ronguered away as high as possible without placing undue tension on the large nerves. If necessary, the lower nerve trunks may then be retracted downward and the stump of the rib exposed between the upper and lower trunks of the brachial plexus. Enough of the rib is ronguered away so as to allow plenty of room for the brachial plexus trunks without any tension or pressure. The neck of the

rib may be left behind since its removal is of no value and adds considerably to the difficulty of the procedure from this approach. The raw edges of the remaining segment should be rounded with a ronguer to avoid sharp margins. The sternomastoid muscle is then sutured as is the platysma. The skin is closed with silk. A firm pressure dressing is applied.

*Postoperatively,* there is a period in which edema and exudate will tend to put pressure on the subclavian artery. During this period the patient should avoid weight-bearing, throwing the shoulders back, carrying a pack, and prolonged use of the affected arm.



FIG. 5.—The tip of the thumb, postoperatively. The necrotic area has demarcated and the tissues beneath have almost completely healed. (Case 1.)

RESULTS

Of nine cases of cervical rib studied, four were symptomatic. In three of these the offending rib was on the right side and in one on the left. The one with symptoms on the left had a peculiar type of abnormality whereby the end of the rib hooked around the subclavian artery (Fig. 7). The symptoms were vascular in nature in three cases and were both vascular and neurologic in one.

The subclavian artery was shut off by the position of attention in six of the nine cases studied and in all the symptomatic cases. The pulse of the subclavian artery was occluded at the clavicle and not by the scalenus anticus muscle. Proof of this fact was obtained by palpating the pulse in the subclavian artery distal to the scalenus anticus muscle. When the patient went to the position of attention, a pulse beat could be felt in the third part of the subclavian artery at the base of the posterior triangle of the neck. At the same time, no pulse could be felt in the axillary, brachial, or radial arteries. Many persons can shut off the pulse by forcibly pressing the shoulders down and back. We consider this of no pathologic significance. The test is considered positive only if the pulse is shut off or markedly diminished by the position which the soldier considers attention. Velinsky[14] studied 108 officer school candidates in order to determine how many normal individuals shut their pulse off at attention. He found three, and of these only one was normal. Of the remaining two, one had cervical rib and the other a history of circulatory disturbances indicative of costoclavicular compression.

Although occlusion of the subclavian artery appeared to be mechanical in nature there is some evidence it may be partly a result of spasm. Frequently the pulse shut off when the position of attention was assumed quickly, but not when it was done slowly. Further, after the pulse had been occluded for a few

seconds it was more readily shut off by a second test. These findings leave one with the impression that a neurogenic factor is added to the mechanical one. In the first instance, a quick stimulus brought about by pressure of the clavicle against the sympathetic nerve fibers produced spasm of the vascular tree. In the second place, the primary occlusion made the blood vessels more sensitive to spasm when the test was repeated.

The pulse was shut off by the Adson maneuver in only one case. In this case, traumatic fibrositis was found present in the scalenus anticus muscle at operation. However, in every case operated upon, the scalenus anticus was found to be producing some pressure on the subclavian artery, proving the necessity of dividing this muscle, as advised by Adson.

Symptoms are more common on the right side in right-handed individuals. In the cases studied, 60 per cent of the cervical ribs on the weight-bearing side were symptomatic while the ribs on the nonweight-bearing side gave symptoms in only 15 per cent of the cases. The right side was considered the weight-bearing side except in left-handed individuals.

The length of the rib and the position of the distal end appear to be important factors in production of symptoms. In all six cases in which the pulse was occluded at attention, the rib was 4 cm. in length or greater, and the shortest distance from the center of the spine to the tip of the rib 6 cm. or greater.

Of the four symptomatic cases one was relieved by medical measures consisting of avoidance of weight-bearing, carrying of packs, or throwing the shoulders back at attention. Exercises aimed at the strengthening of the levator scapulae and trapezious muscles were given.[6] Surgery was necessary in three cases. A scaleniotomy was performed and the greater part of the rib was removed. The scalenus anticus was found to be producing considerable pressure on the subclavian artery in all three cases. It was greatly hypertrophied in all cases and in one it had two heads of insertion on the first rib. In one of these cases in which a scaleniotomy had previously been done, the muscle ends had grown back together again. Some of the fibers had become inserted into the artery. Recurrence can be avoided by dividing the muscle low down near its insertion so that it may retract. The results were uniformly good, with no complications.

One case had occlusion of the radial artery by thrombosis. The brachial pulse was present, but could be occluded by assuming attention. Gangrene had begun in three fingers. The radial pulse beat returned six weeks after operation. The necrotic areas on the thumb and little finger demarcated and healed. The sloughing stump of the middle finger rapidly healed. The hair grew back on the arm and the skin regained its normal texture. All the degenerated nails came off and new ones replaced them (Fig. 6). His arm rapidly regained its function. After operation, the brachial pulse would no longer shut off when he came to attention. Two men were returned to six months temporary limited duty, with the intention of placing them on full duty later. One man was placed on full general service two months postoperatively, at his own request.

REPORT OF CASES

**Case 1.**—A white male, age 30, was admitted to the Regional Hospital, Camp Joseph T. Robinson, Arkansas, August 11, 1944, with a painful draining sinus of the middle finger of the right hand of 11 months duration. His past history and family history were irrelevant. He gave a history of first having had trouble around Thanksgiving of 1942 during a spell of cold weather, while employed as a civilian locomotive fireman in Louisiana. Symptoms were soreness at the tip of the index finger, blueness of the nail, as if it had been "mashed with a hammer," and whiteness, numbness, and coldness of the hand, accompanied by a tingling sensation. This condition continued for the remainder of that winter and neither progressed nor improved until the onset of warm weather in April, when symptoms disappeared. The finger healed and he remained well until after

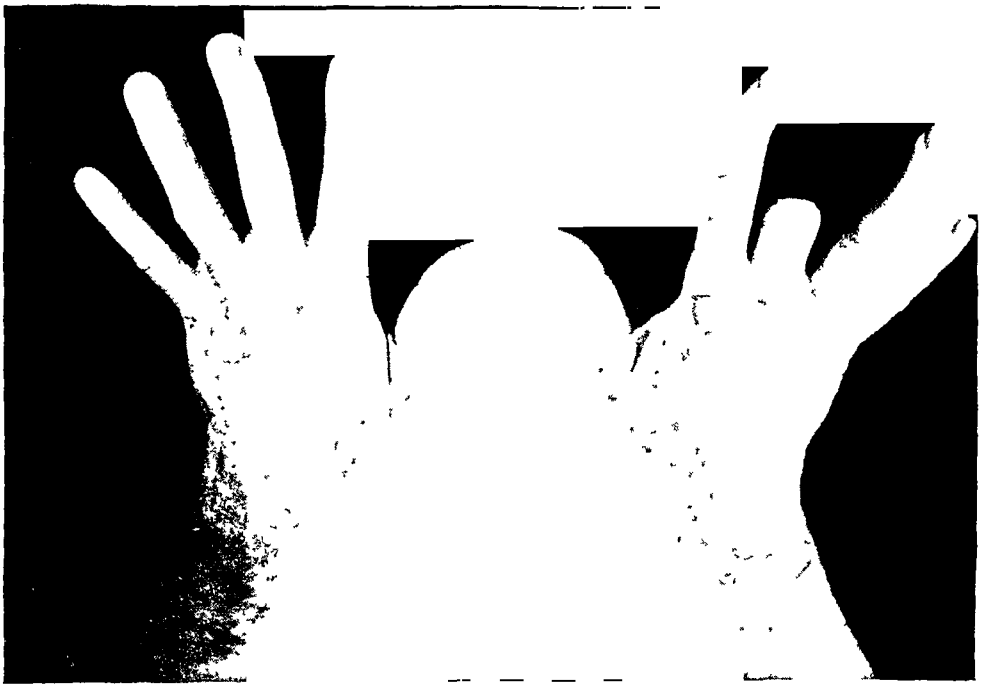


FIG. 6.—The hands of Case 1 two months after surgical removal of a right cervical rib. Note the marked improvement in blood supply as indicated by the quality of the skin and the color. The nails, atrophic from preoperative ischemia, are in the process of separation and are being replaced by new ones. (Case 1.)

his entrance on active duty December 15, 1943. In January, 1944, while he was taking his basic training in Louisiana, symptoms returned, but this time it was the middle finger of the right hand that was first involved. The tip of the finger became sore, and the nail became discolored as had the one on the index finger previously. The skin began to peel. The right hand ached a great deal and became blanched at times, particularly on cold days. An aching pain developed along the inner side of the right arm and shoulder with progressive weakness and atrophy of the arm. He began to rely more and more on the use of his left hand. Soon the condition became so severe that the right arm would become numb and white when he attempted to shave and the razor would fall from his hand. In spite of this, he completed basic training. Infection developed around the nail of the right middle finger and the nail was removed at a dispensary. Even though the wound did not heal, the true nature of his condition was not recognized at that time. He was transferred to Camp Joseph T. Robinson, Arkansas, April 20, 1944.

Roentgenologic examination of the right hand revealed some rarefaction of the bones and a loose piece of bone in the distal phalanx of the middle finger. On March 5, 1944, the distal phalanx of the middle finger was amputated. The wound failed to heal and continued to discharge until August 20, 1944, when a reamputation was performed and this time soft-tissue flaps were designed. The wound healed in the hospital, but broke down very soon after return to duty. On September 14, 1944, a cervical rib was discovered and attention was directed to the true nature of his condition for the first time. At this time the radial pulse was absent. The brachial pulse was still present at the antecubital space. A scaleniotomy was performed. The immediate postoperative results were apparently good. The radial pulse was reported to have returned shortly after the operation. The lesion on the middle finger "healed miraculously." In spite of these apparent immediate beneficial results, the original symptoms rapidly returned when he resumed training. His right hand would become numb and cold while drilling, particularly on cold days. The wound on the middle finger broke down again. In addition to this, a similar process began on the thumb and little finger. He was readmitted to the hospital when on examination it was discovered for the first time that the structure of counter pressure obliterating the subclavian artery against the first rib was not the scalenus anticus muscle, but the clavicle. The proof of this finding was: (1) the cervical rib could be clearly felt in the posterior triangle of the neck just behind the clavicle with the subclavian artery intervening; and (2) when the position of attention was assumed the clavicle pressed firmly against the expanded end of the cervical rib and the brachial pulse disappeared. The subclavian pulse, however, could be clearly felt in the posterior triangle of the neck well lateral to the scalenus anticus muscle. When the shoulder was forward the pulse beat could be felt in the brachial artery in the antecubital space. The Adson maneuver did not obliterate the pulse. No pulsation could be detected in the radial artery at all. There was trophic disturbance of the right hand. The skin was thin and scaly, hair had ceased to grow, and the nails were thin and brittle. The arm was smaller in diameter than the left. There was an amputation stump on the middle finger on the end of which was a nonhealing wound; the proximal phalanx only remained. There was beginning gangrene at the margin of the nail on the little finger and at the tip of the thumb (Fig. 5).

On January 2, 1945, he was operated upon a second time. A scaleniotomy was performed and the greater part of the first rib was removed. It was found at operation that the subclavian artery was constricted considerably by the scalenus anticus muscle. The muscle ends had reunited since the previous operation. Some of the muscle fibers were actually inserted into the artery. The cervical rib was behind the third portion of the subclavian artery, its expanded tip articulated with the first rib. It was obvious that the subclavian artery could have been occluded between the expanded end of the cervical rib and the clavicle. Postoperatively, the brachial pulse no longer shut-off at attention, and in six weeks the radial pulse had returned. The condition of the hand and function of the arm rapidly improved. The necrotic area on the thumb separated by a definite line of demarcation (Fig. 5). The raw areas on the middle and little fingers also healed rapidly. The atrophic nails came off and new ones grew in their place (Fig. 6).

On March 1, 1945, he was operated upon for a revision of the amputation stump of the middle finger. A small area of osteomyelitis was found at the tip of the bone. *Staphylococcus aureus hemolyticus* was cultured. The wound was closed and healed *per primam*. At the time of this writing, eight months after operation, he is symptom-free, and has returned to duty.

COMMENT.—Symptoms of ischemia developed during the cold weather and improved in the summer, indicating that there was a spastic factor added to the mechanical factor. The mechanical factor was brought about by an obliteration of the subclavian artery between the expanded end of a high cervical

rib and the clavicle. The scalenus anticus muscle, although a factor, was not important in the production of symptoms in this case. A scaleniotomy was first performed, with temporary beneficial effect. Symptoms promptly recurred when he returned to drilling. The divided scalenus muscle had reunited by scar tissue. A second operation, consisting of scaleniotomy and removal of a portion of the cervical rib, resulted in a cure. Roentgenologic examination, December 6, 1944, showed a rarefaction of the bones. Following operation, the calcium was again deposited in the bones. This case demonstrates that a scaleniotomy should be performed low, near the first rib, so that the upper end of the muscle can retract. Otherwise, the muscle ends will grow together again. It also shows the importance of removal of a part of the first rib in addition to scaleniotomy.

**Case 2.**—A white male, age 22, with over four years service, was admitted to Regional Hospital, Camp Joseph T. Robinson, Arkansas, February 19, 1945, complaining of pain along the medial side of the right arm and hand, together with a tingling sensation in the ring and little fingers. Six years before admission, he had noticed that the right hand would periodically become numb or "dead." This sensation lasted only a few minutes and was relieved by moving the shoulder. He suffered an attack once while painting a shelf at a low level and the paint brush fell from his hand. Four years ago, shortly after induction, he noticed attacks of pain along the ulnar side of the forearm brought on by marching. Pain occurred with equal regularity while marching with or without a pack. He gradually became worse until even writing or typing would cause the right arm to "go to sleep."

In January, 1945, the condition suddenly became worse. Discomfort consisted of tingling along the median aspect of the right hand and forearm, and pain in the angle of the scapula. Neurologic examination showed hypo-esthesia along the distribution of the ulnar nerve, no reflex changes, fibrillary twitching, or atrophy. It was found that when he assumed the position of attention, his brachial pulse was obliterated. The Adson maneuver was negative. Roentgenologic examination showed a long, slender, right cervical rib, measuring 6.5 cm. from its tubercle to the tip. Physical examination was otherwise negative. On March 9, 1945, a scaleniotomy was performed and the greater part of the cervical rib was removed. The subclavian artery was constricted considerably by the scalenus anticus muscle. Some of the posterior muscle fibers and the posterior sheath were actually attached to the artery. The lower roots of the brachial plexus were stretched over the sharp upper margin of the cervical rib.

Postoperatively, the numbness and tingling along the course of the ulnar nerve gradually cleared up. Two months postoperatively, he was entirely symptom-free and his pulse was no longer obliterated by the position of attention.

COMMENT.—This patient had manifestations of both vascular and neurologic disturbances. Depression of the shoulder in painting produced attacks. Swinging the arms in marching produced irritative neurologic symptoms from friction of the lower trunk of the brachial plexus being rubbed over the sharp margin of a cervical rib. The pulse was not occluded by the scalenus anticus muscle, but it was completely obliterated by the clavicle when he assumed the position of attention. Some fibers of the scalenus anticus muscle were adherent to the subclavian artery. This indicates that all the fibers of the muscle must be carefully divided during a scaleniotomy.

Case 3.—A white male, age 18, entered on active duty January 23, 1945. One month later he noticed numbness in the left arm while carrying a pack on long hikes. Later in March, he noticed similar numbness in his left hand on waking in the morning. Roentgenologic examination revealed a cervical rib on the left side. On physical examination, it was found that the pulse to the left arm was shut off by the position of attention and by the Adson maneuver. He was operated upon May 28, 1945. The scalenus anticus muscle was divided and the greater part of the left cervical rib was excised. The thoracic duct was exposed during the procedure, but it was not injured.

The operative findings were as follows: The scalenus anticus muscle, which was greatly hypertrophied, had two heads of insertion into the first rib, and was adherent to the subclavian artery in its lateral part. The artery was compressed by the scalenus

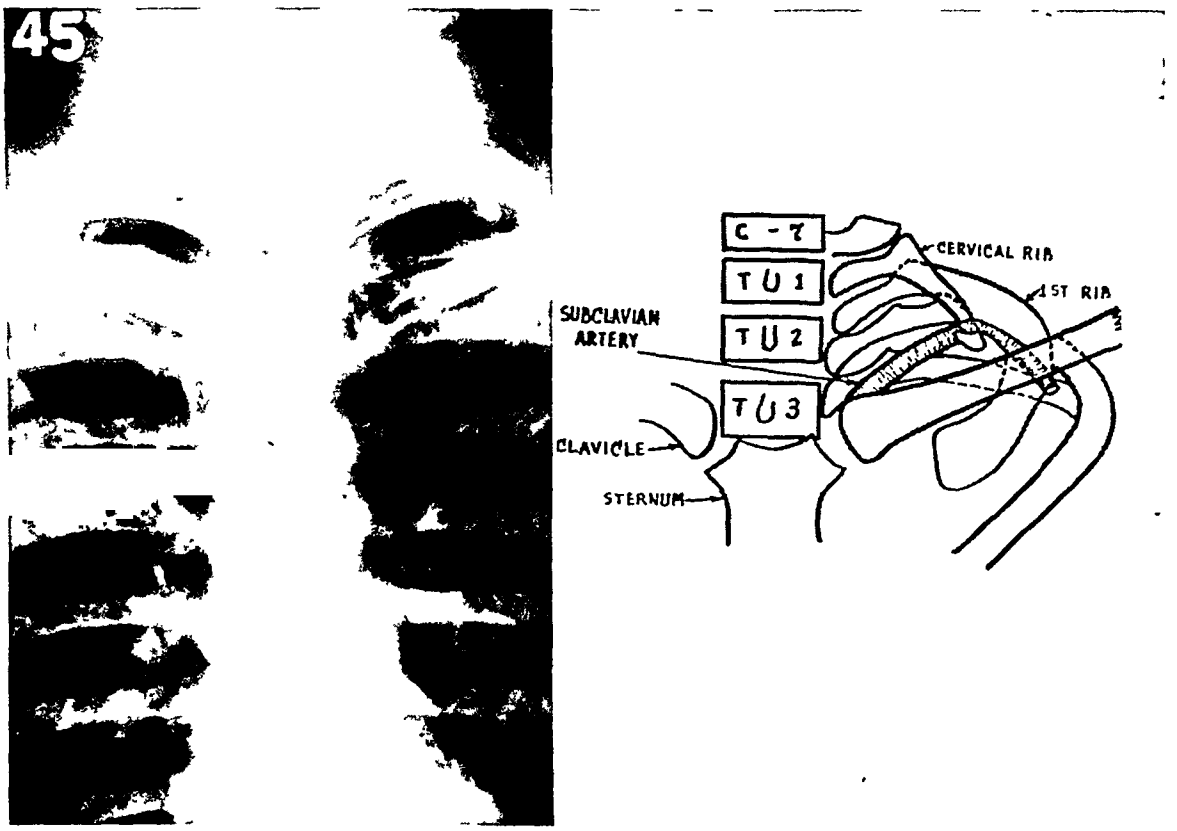



FIG. 7.—A left-sided cervical rib producing symptoms because of an unusual abnormality in which the subclavian artery was suspended from a bony hook. The deep groove in which the subclavian artery lies represents an attempt on the part of the neurovascular structure to cut through this rib during embryonic life. (Case 3.)

anticus muscle and it was elevated and pulled upward into the neck by adhesions to the scalenus muscle and to the aberrant rib. It was also adherent to the brachial plexus by numerous adhesions. The distal end of the cervical rib was situated just behind the lateral border of the scalenus anticus muscle, and was hooked around the third part of the subclavian artery. A fibrinous band extended from the tip of the cervical rib to the first rib.

Postoperatively, the patient had no complications. He returned to temporary limited duty at the end of the third week at his own request. One month later he requested and was given full military duty. The pulse no longer shut off at attention.

COMMENT.—It is uncommon to have symptoms on the left side. In this case, however, there was an unusual abnormality in that the first rib was hooked around the third part of the artery. The Adson maneuver was positive,

probably because of the fibrositis in the muscle, traumatic in nature, as a result of intermittent pressure from the clavicle.

Case 4.—A white male, age 18, entered on active duty October 16, 1944. In May he noticed a tingling sensation in the right arm while carrying a pack. The fingers became blanched and he rubbed and shook his hands to promote circulation. Shortly thereafter he noticed that, while leaning back in the theater watching a show, his arms would "go to sleep." He wondered why his feet did not go to sleep also. While on long hikes his right arm and hand would become numb requiring him to shift the rifle and readjust the shoulder straps of his pack to obtain relief. While both arms were affected

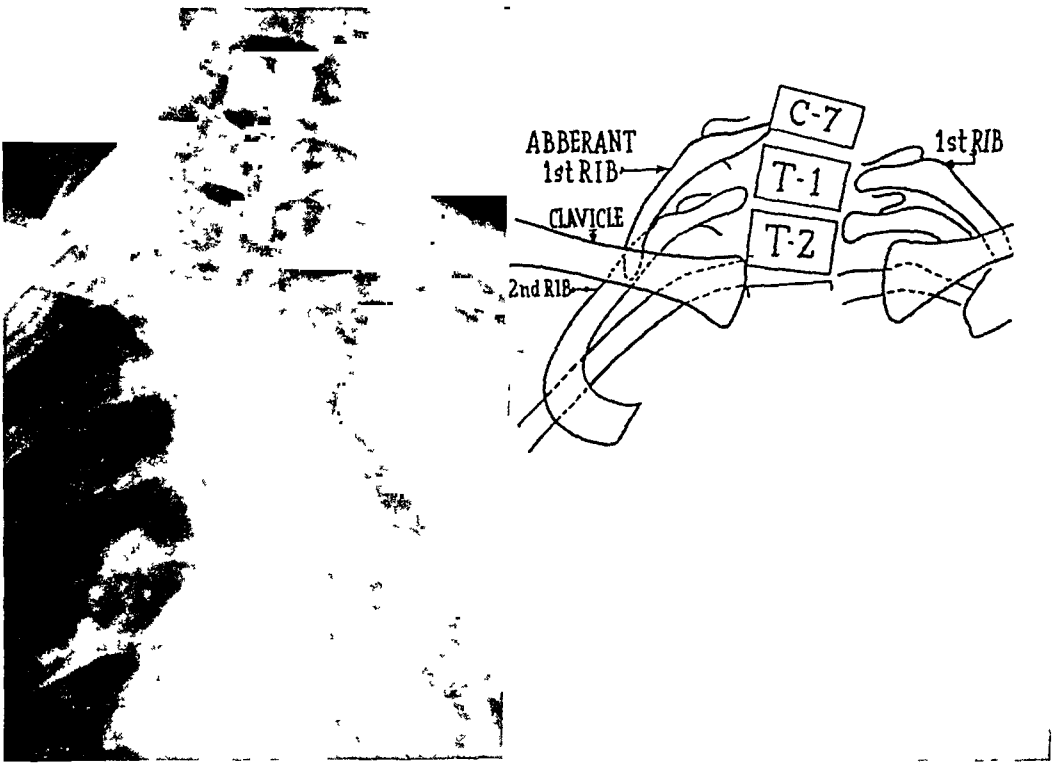



FIG. 8.—An abnormal first thoracic rib. The developmental abnormality of this case is clearly shown to be due to too rapid caudad progression of the neurovascular structures to the arm shearing off the distal part of the first thoracic anlage during embryonic life. As pressure was applied to the distal end of the rib, the proximal end was levered more cephalad. Compare the relative level of the heads of the first thoracic ribs on each side and note that the one on the right side is higher.

at times, the condition was more noticeable on the right side. Physical examination revealed a cervical rib in the right posterior triangle of the neck. When the shoulders were thrown back the pulse shut off on both sides, more readily on the right. Neurologic examination was negative; there was no trophic disturbance. Roentgenologic examination revealed a bilateral cervical rib; the right being the longer measured 4 cm. in length and the tip was 6 cm. lateral to the midline. He was given a period of limited duty and was told to avoid carrying a pack, weight-bearing, or throwing the shoulders back at attention. He was instructed in exercises to strengthen the levator scapulae muscles and elevate the shoulders.[6] On July 23, 1945, when he was called in for reëxamination, he was symptom-free.

DISCUSSION.—The vascular symptoms in these cases of cervical rib were the result of occlusion of the subclavian artery by the clavicle acting as the factor of counter pressure. The proof of this is that when the patient threw his shoulders back shutting off the pulse to the arm, the subclavian artery could be felt pulsating in the posterior triangle of the neck. If the scalenus anticus muscle was the factor of counter pressure, one would expect the pulse to be occluded in the second part of the subclavian artery as well. If the occlusion was due entirely to vasospasm resulting from sympathetic irritation, one would not expect the axillary artery to be occluded at the same time as the brachial since they have different sympathetic nerve supply. However, a spastic factor was superadded to the mechanical one, as previously mentioned.

The strenuous physical exertion of basic military training tends to produce symptoms by: (1) elevation of the thoracic cage from excessive use of the muscles of extraordinary respiration; and (2) carrying of a pack and prolonged standing at attention, which causes the shoulder to be pushed down and back resulting in vascular and nerve pressure.

Four patients were seen in whom vascular symptoms were present without any cervical rib. In all of these, the pulse was obliterated by position of attention, but not by the Adson maneuver. They were treated by being relieved from carrying a pack, by exercises designed to elevate the shoulder by strengthening the trapezius and levator scapulae muscles. They were instructed not to throw the shoulders back at attention. Costoclavicular syndrome is considered a suitable term to identify such a type of case. The cause of this condition is believed to be due to a narrowing of the space between the clavicle and the first thoracic rib.

In the cases with cervical ribs, here reported, the costoclavicular factor appeared to predominate in those with long laterally placed ribs and the subclavian artery was occluded in the third part. In the case of a more medially placed rib, the scalenus anticus was found to be an important element of counter pressure and the second part of the subclavian artery was usually involved.

The "Adson maneuver" is a test designed to determine the rôle played by the scalenus anticus. Pressure is supposed to be exerted on the subclavian artery by turning the head toward the side of the lesion, hyperextending the neck and taking a deep breath. Turning of the head in this manner would not be expected to put tension on a normal scalenus muscle since the muscle should reciprocally relax in the same manner in which the quadriceps relax when the hamstrings contract. The muscle should become longer and thinner without any change in tension. However, if this muscle was the seat of fibrositis or stretched beyond physiologic capacity, as in older age-groups, tension would develop. Ochsner[9] proved the presence of fibrositis in his cases. In our series, a younger age-group, the Adson maneuver was positive only in one rib case.

Surgery is aimed at increasing the size of the costoclavicular space by removing the scalenus anticus muscle and the cervical rib.

SUMMARY

Up until the present time, it has been generally believed that symptoms from cervical rib are produced in many cases by pressure from the scalenus anticus muscle. This we have found to be partly correct. However, in the cases presented here of young men in military service, it was found that the important structure of counter pressure is the clavicle. Vascular symptoms are produced by the subclavian artery being occluded between the cervical rib and the clavicle. In these cases the pulse was occluded partially or completely by the clavicle when the position of attention was assumed. When surgery is indicated in such cases, a partial excision of the cervical rib should be performed in addition to scaleniotomy.

In addition to crowding from a cervical rib and a hypertrophied scalenus anticus muscle, the costoclavicular space may be further narrowed by: (1) elevation of the thoracic cage; and (2) depression of the shoulder. The first conditions are brought about by excessive use of the muscles of extraordinary respiration such as the sternocleidomastoids and the scalene group; and the second, by carrying a pack, and prolonged periods of standing in the position of attention.

The longer the rib, the greater the possibility of costoclavicular compression. Ribs 4 cm. or more are liable to be symptomatic. The more laterally placed the tip of the rib is the more liable it is to produce symptoms. Ribs which extend 6 cm. or more lateral to the center of the spine were found to be symptomatic. Right-sided cervical ribs produce symptoms four times more often than those on the left.

Nine cases of cervical rib are here reported, in six of which the radial pulse was occluded in the position of attention. All but one of these had vascular symptoms. One case had thrombosis of the radial artery and beginning gangrene of three fingers of the right hand. Three cases were operated upon, at which time a scaleniotomy and partial removal of the cervical rib was performed. There was no mortality and no sequelae. Results were all good.

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# RESECTION OF THE LEFT LOBE OF THE LIVER FOR MESENCHYMOMA

## REPORT OF CASE

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RESECTION of the entire left lobe of the liver has been reported on four previous occasions. Keen[1] removed the left lobe, in 1899, for carcinoma, using the cautery, catgut ligatures and iodoform packing. Peck[2] resected the left lobe for an angioma weighing about 1.8 Kg. He used the clamp and ligature method for the control of hemorrhage. Pickrell and Clay[3] reported the successful removal of the left lobe in three cases. They emphasized the fact that total extirpation of the left lobe of the liver is more easily and safely accomplished than excision of only the part bearing the lesion. The reasons for this are: the thinness; relative avascularity; and greater capacity for holding sutures which the insertion of the round ligament confers on the line of junction of the two lobes. Lobectomy offers the additional advantage of wider excision of the pathologic tissue. Their method of resection consisted of cutting between two rows of mattress sutures placed in the interlobar sulcus. The conditions for which they performed left lobectomy were: carcinoma, hemangioma and gumma. (The last was diagnosed as carcinoma or a giant tuberculoma at the time of operation.) Van Prohaska[5] has recently reported excision of the left lobe for a solitary metastatic carcinomatous nodule. Resection was accomplished by cutting alongside hemostatic mattress sutures. Clamps and ligatures were used for some of the larger vessels as they were encountered. There have been many reports on partial hepatectomy[1, 4, 6] but this paper deals only with resection of the entire left lobe of the liver.

The performance of left lobectomy of the liver is rare enough to warrant this single case report of successful resection for an unusual lesion.

**Case Report.**—J. T., a six-year-old white boy, was admitted to the Babies Hospital, November 20, 1944, because of an epigastric mass. One week previously he complained of cough and vomiting and was treated for acute coryza. The abdominal mass was discovered during the physical examination for that illness. The parents had no previous knowledge of the mass nor of any symptoms referable to the abdomen. The mass was not observed during physical examination before tonsillectomy one year prior to this admission. The personal and family histories were noncontributory.

Examination revealed a tall, thin boy who did not appear acutely ill. His temperature, pulse and respirations were normal. Blood pressure 96/74. The physical findings were within normal limits except for examination of the abdomen. There was a firm, nontender mass in the epigastrium somewhat to the left of the midline—measuring about six centimeters in diameter. It was well forward in the abdominal cavity and not separable from the liver, the edge of which was palpated one centimeter below the costal margin in the right nipple line and which moved with the mass during inspiration, though with a smaller

excursion. Percussion over the mass was dull; over the left hypochondrium tympanitic. No other mass or organ was palpable in the abdomen. The hemoglobin was 14.5 Gm. and the red blood cells 5,040,000. The leukocyte count was 6,800, with 45 polymorphonuclear cells, 51 lymphocytes, 3 monocytes and 1 eosinophil. The urine analysis, platelet count, bleeding and coagulation times were all within normal limits. The nonprotein nitrogen was 36.9, and the blood sugar 59 mg. per cent. The sedimentation rate was 2 mm. in the first half-hour and 6 mm. in one hour. The tuberculin test was negative to .01 mg. The Kline test was reported negative.

Roentgenologic examination of the gastro-intestinal tract showed that the stomach was compressed and displaced laterally by a large mass which projected into its medial aspect. The stomach emptied readily, all of the barium being evacuated at the end of one hour.



FIG. 1.—Cut-surface of the inferior half of the tumor. The left margin represents the free border of the left lobe.

On December 7, 1944, under ether anesthesia, a celiotomy was performed through an upper left rectus incision. A large cystic mass, measuring 7.5 cm. in diameter, was found taking up most of the left lobe of the liver and projecting from its under surface. A thin shell of liver tissue remained over the mass anteriorly (Fig. 1). The right lobe appeared to be perfectly normal. Aspiration in several places yielded approximately 60 cc. of dark brown fluid resembling old blood. The liver was mobilized by cutting the falciform ligament near its diaphragmatic attachment and by incising the left triangular ligament. The dissection began in the interlobar fissure on the inferior surface of the liver, exposing the left hepatic bile duct and the left branches of the hepatic artery and portal vein. These were individually ligated with braided silk. The left lobe was then resected by cutting through the liver substance at the fissure. The hepatic veins from the left lobe were ligated during this dissection. Remarkably little bleeding occurred during the entire procedure. A few interrupted silk sutures were used through the falciform ligament and the inferior surface of the liver to cover part of the cut area. The remaining cut-surface of liver tissue was then covered with a layer of oxidized cellulose gauze and this was left *in situ*. The abdomen was closed in layers, without drainage. The patient received 300 cc. of whole blood and 100 cc. of normal saline during the procedure. He was given another 250 cc. of whole blood later in the day.

He made an uneventful recovery, and was discharged on his 14th postoperative day. On February 8, 1945, he had no complaints, and his wound was well healed. On May 14, 1945, he was symptom-free, and presented normal findings on examination. He was last seen on January 7, 1946 (about thirteen months postoperatively). He looked well, was developing normally, gaining weight and had no complaints.

FIG. 2

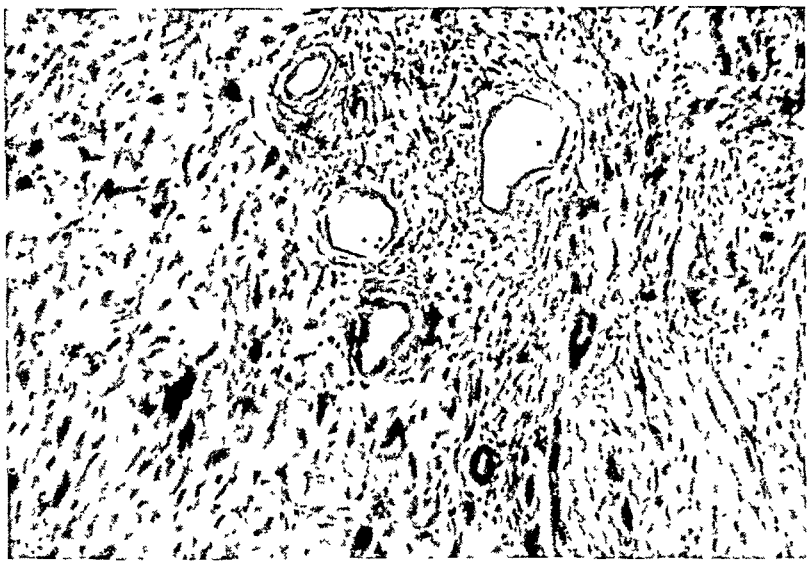


FIG. 3

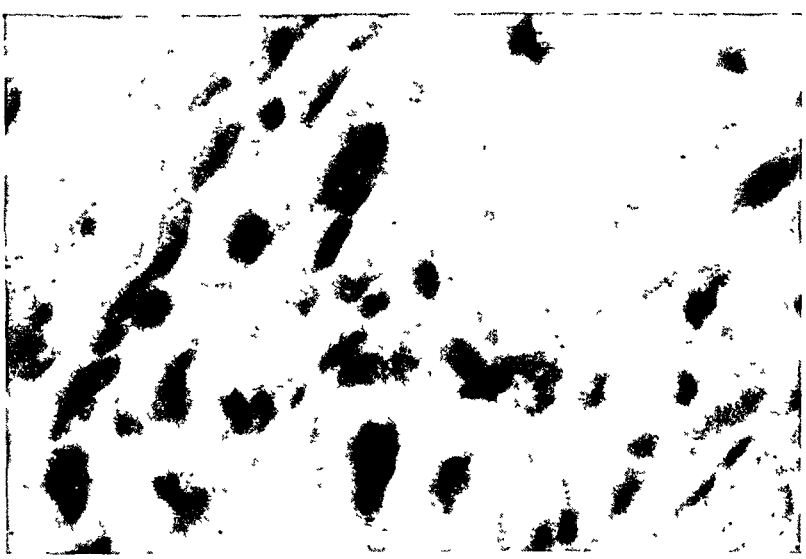


FIG. 2.—Section taken near the periphery of the tumor showing angiomatous and mesenchymal tissue. (x1750)

FIG. 3.—High magnification of mesenchymal area showing multinucleated cells and embryonal fat cells. (x6250)

A summary of Dr. Dorothy H. Andersen's pathologic report follows: "The specimen consists of the left lobe of the liver which contains a large round tumor mass bulging from the inferior surface. The entire specimen weighs 318 Gm. The tumor measures 7.5 cm. in diameter. The liver measures 13 cm. in the transverse plane and 6.5 cm. in thickness. The surface of the mass varies in color and consistency. On section, the mass

appears to be composed of tumor, portions of which have degenerated. The tumor is divided by sheaths of fibrous tissue into smaller areas, some of which are necrotic (Fig. 1). The largest such area occupies about one-quarter of the mass. Most of these areas are occupied by grayish-buff, translucent tissue which is soft. Others have a smooth lining and contain bloody serous fluid. The liver parenchyma itself appears to be normal. Microscopic sections show that the liver has been partly destroyed and replaced by an expansile and, to some degree, an infiltrating tumor of the most bizarre and complex appearance (Fig. 2). It varies so much in different areas that it is extremely difficult to describe. In general, it seems to be made up of a mesenchyme-like tissue which varies from ordinary embryonal mesenchyme by the fact that, not infrequently, its cells assume a bizarre multinucleated aspect. In some areas the mesenchyme seems to differentiate by the formation of capillaries. In others, there are nodules suggesting the appearance of lipoblastic tumor tissue; very occasionally, small areas of spindle-shaped tumor cells appear (Fig. 3). No satisfactory name has been devised for this type of tumor, especially in this solitary form which is distinctly neoplastic. Although expansile, it does not appear invasive and is everywhere enclosed by the thick fibrous capsule. Since it is apparently essentially a tumor of the mesenchyme, it will be called a mesenchymoma of the liver."

SUMMARY

(1) Successful left lobectomy for an unusual primary tumor of the liver is presented.

(2) Mobility of the liver is achieved by cutting the falciform ligament at its diaphragmatic attachment and by incising the left triangular ligament.

(3) A method is presented for controlling hemorrhage, the major problem in liver resections. This is accomplished by ligating the left branches of the hepatic artery and portal vein in the interlobar fissure. The hepatic veins are ligated as encountered.

(4) Oxidized cellulose gauze may be used effectively to check the bloody ooze from the cut-surface of the liver (after all major bleeding has been controlled).

We desire to express our appreciation to Dr. Allen O. Whipple for his advice and assistance.

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# POSTOPERATIVE ATELECTASIS AND PNEUMONIA

## DIAGNOSIS, ETIOLOGY AND MANAGEMENT BASED UPON 1,240 CASES OF UPPER ABDOMINAL SURGERY

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DURING THE PERIOD July, 1941 to October, 1945 there were 1240 upper abdominal operations completed at the Hospital of the University of Pennsylvania. On the basis of data obtained from this group of patients it is our opinion that the incidence of postoperative atelectasis and pneumonia can be sharply reduced if a rational prophylactic regimen is observed prior to surgery, during operation, and immediately following operation. Indifferent attention to such a program will inevitably be followed by a rise in postoperative respiratory morbidity, particularly in individuals to whom general anesthesia has been administered.

There have been scores of papers on the subject of postoperative pulmonary complications. Certain broad principles relating to etiology and treatment have been established, and, on the basis of these, what formerly constituted one of the chief hazards of surgical convalescence has now become much less of a danger, despite the fact that surgeons today are performing more extensive operations, and are likewise subjecting older and older patients to surgical intervention. The background for this decrease in respiratory morbidity is a comprehensive one. Among the contributing factors should be included the development of anesthesiology as a medical specialty, greater knowledge of the preoperative preparation of the surgical patient, the application of physiologic principles to therapy, the introduction of chemotherapy and antibiotics, blood banks, and blood substitutes. The combination of these and other advances enables the surgical patient to anticipate a postoperative course marked by minimal disturbance of function. This paper will not present any fundamentally new concepts, therefore, but will concern itself with details, the minutiae which are essential to the successful application of well-recognized general principles.

As stated above, this study was begun in July, 1941. An analysis of the first 250 cases was completed in December, 1942 (Series I). Certain facts became apparent at once. The incidence of postoperative atelectasis and pneumonia was 11.0 per cent for patients receiving inhalation anesthesia, and only 4.2 per cent in the group given spinal anesthesia. Since it has been conclusively proven by many investigators[1, 2] that the anesthetic agent and technic are not major factors in postoperative morbidity, it was evident that something was amiss. Accordingly, a positive program was adopted for the management of patients scheduled for inhalation anesthesia. An analysis of the next 990 upper abdominal operations (Series II—December, 1942 to October, 1945)

demonstrated the efficacy of the change. Following spinal anesthesia the incidence of atelectasis and pneumonia in the postoperative period had remained essentially unchanged (5.0 per cent), whereas after inhalation anesthesia the incidence had decreased to 4.1 per cent. Since these data have proved statistically significant, it seemed of interest to report them and to attempt an explanation for our experience.

## METHOD OF STUDY

There are two general surgical services at this hospital. One prefers general anesthesia, the other spinal anesthesia. These services use the same wards, operating rooms, anesthetists, interns and nursing staff. They care for the same general type of patient, since admissions are alternated from the receiving ward or are sent in by a large but relatively constant group of referring physicians. There has been, therefore, opportunity for more or less standardizing such factors as preoperative preparation of the patient, the ability of the anesthetist, surgical technic and skill, and postoperative care, leaving as the outstanding variable the method of anesthesia. This latter, of course, is not the sole variable, but the 1,240 cases are as carefully controlled as is possible in the average clinical case study.

The value of a statistical study of clinical material varies directly with the accuracy of each individual observation. In this particular instance accuracy in diagnosis determines statistical reliability. Failure to recognize even a few cases or inclusion of doubtful ones will alter final figures considerably unless the series be much larger than those usually reported. For this reason data gathered from hospital record rooms is more liable to error than is data obtained directly from each patient as that patient is being treated. The authors of this paper have, therefore, followed each case during the entire postoperative course until discharge from the hospital. Careful progress notes have been made in each instance.

It is unfortunate that diagnostic criteria for postoperative atelectasis and pneumonia have not been standardized, and many surveys have not indicated clearly the basis on which diagnoses have been established. There is general agreement as to the clinical picture and radiologic findings of the so-called "massive collapse," described first by Pasteur. Lobar atelectasis is also readily recognized. There are, however, a great many patients whose pulmonary status is equivocal. Diagnosis for these individuals ranges from "bronchitis" through "patchy or lobular atelectasis" to "pneumonitis or pneumonia." It is this larger group for which diagnostic standards will be discussed, for they form the borderline cases which are so difficult to evaluate.

We have made a diagnosis of patchy or lobular atelectasis in the presence of the following findings:

*Symptoms.*—1. *Cough:* Dry at start, soon becoming productive tenacious mucus, or mucopurulent secretions.

2. *Respiratory Distress:* A sense of discomfort over the lung field, vague tightness in the chest, or dyspnea.

*Signs.*—1. *Inspection:* Asymmetrical respiratory movements (retraction of affected side on inspiration, restriction of movement on affected side); slight cyanosis (not essential).

2. *Auscultation:* Diminished or absent breath sounds, râles (these may be coarse or fine).

3. *Percussion:* Dullness (not essential).

4. *Vital Signs:* Rise in pulse rate, respiratory rate, or temperature (the usual range in patchy atelectasis is 99–101 degrees F.).

*Roentgenologic Findings.*—1. *Linear Shadows:* Well-described by Fleischner, Hampton and Castleman,[3] indicative of collapse of alveoli.

2. *Hypoventilation:* Increased density of lung tissue (decreased air-bearing), prominent trunk shadows.

3. *Elevation of Diaphragm, and Reduced Excursion of Diaphragm:* Seen in majority of upper abdominal cases whether or not signs and symptoms indicate pulmonary dysfunction.[4]

4. *Mediastinal Shift:* An uncommon finding unless the collapse involves many areas unilaterally.

If the clinical course is prolonged, if the febrile reaction decreases only slowly, if toxemia is evident, and if there are roentgenographic signs of consolidation, a diagnosis of bronchopneumonia is made.

The differential diagnosis between bronchitis and lobular atelectasis presents the greatest problem. If the only objective finding is a productive cough, with little febrile response, and little evidence of respiratory distress, the former diagnosis seems more accurate. Admittedly, there are instances in which we have erred, but our tendency has been to include doubtful cases in the category of major pulmonary complications.

All the data have been subjected to statistical analysis according to the method of chi-square.

## RESULTS

I. *Incidence.*—The results of the entire group of cases are shown in Table

TABLE I

TOTAL INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING 1,240 UPPER ABDOMINAL OPERATIONS

| | No. of Cases | No. of Complications | Per Cent |
|---|---|---|---|
| Series I..... | 250 | 19 | 7.6 |
| Series II..... | 990 | 49 | 4.9 |
| | 1,240 | 68 | 5.5 |

I, where it is seen that the incidence of postoperative atelectasis and pneumonia cases was 5.5 per cent in 1,240 cases of upper abdominal surgery. This incidence of 5.5 per cent must be compared to that expected in a general surgical service with all types of operations. Representative figures are those of Eliason and McLaughlin[5] of 1.38 per cent in 22,962 cases, and of Taylor, *et al.*[6] of 1.2 per cent in 12,349 cases. Thus, as has long been known, the incidence of major

pulmonary complications in the postoperative period is distinctly greater after surgery in the upper abdomen.

II. *Anesthetic Method.*—Table II indicates the incidence of postoperative atelectasis and pneumonia in relation to the use of general anesthesia, spinal anesthesia, or a combination of these two methods. Analyzed statistically, there is no significant difference between the three groups of cases. Of statistical

TABLE II

INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO ANESTHETIC METHOD

| | General | | | Spinal | | | Spinal Plus General | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cases | Compl. | % | Cases | Compl. | % | Cases | Compl. | % |
| Series I..... | 90 | 10 | 11.1 | 144 | 6 | 4.2 | 16 | 3 | 18.7 |
| Series II..... | 343 | 14 | 4.1 | 543 | 27 | 5.0 | 104 | 8 | −7.8 |
| | 433 | 24 | 5.5 | 687 | 33 | 4.8 | 120 | 11 | 9.0 |

significance, however, is the breakdown of cases in the group "general anesthesia." Series I shows a significant difference in incidence from that found for the entire group, and from that found in Series II.

These observations confirm a fact, also well-established, that the anesthetic method need not influence the incidence of respiratory complications in the postoperative period. Ferguson and Latowsky[7] have published data, however, which indicate that general anesthesia is followed by major pulmonary complications four times more frequently than is spinal anesthesia. In Series I of our own figures the incidence in favor of spinal anesthesia is almost 3:1. How can one reconcile these two viewpoints? Why do many surgeons and internists insist, on the basis of personal experience, that spinal anesthesia is preferable if atelectasis or pneumonia are to be avoided?

The explanation for these differences in opinion lies in the fact that general anesthesia is more hazardous unless administered skillfully, and unless the patients receive conscientious, competent supervision in the immediate six hours postoperatively. Ferguson and Latowsky's figures were gathered in an institution where nurse-anesthetists or interns administered all of the general anesthesia, and where the importance of immediate postoperative care was not stressed repeatedly by the anesthesia and surgical staffs. Series I in this study represents somewhat similar conditions, particularly as regards postoperative management. This was entirely left up to the initiative of the nursing staff. In some instances care was excellent. In others the rationale underlying intelligent treatment of the unconscious patient was not appreciated at all. Postoperative rounds were not started until the whole schedule of cases was completed, so that physician supervision was often delayed for hours unless emergency measures were required. With such a regimen the incidence of postoperative atelectasis and pneumonia was significantly lower in those patients given spinal anesthesia. It is our opinion, therefore, that with mediocre anesthetic skill and indifferent or uninformed postoperative attendants spinal anesthesia is the safer method. If certain well-recognized measures are adopted, however, this need not be the case.

As stated in the introduction, we instituted a definite program for the management of surgical patients scheduled for general anesthesia when Series I revealed that our incidence of pulmonary complication was so much higher following this type of anesthesia. Table II indicates the value of this prophylactic program, the details of which will be presented:

## PROPHYLACTIC REGIMEN

A. *Preoperative.*—(1) All cases with acute upper respiratory infections were postponed for one to two weeks unless the problem was a surgical emergency.[8, 9]

(2) Patients with recent irritation of the respiratory passages were given larger doses of atropine, since such individuals tend to pour out a greater amount of secretion in response to inhalation anesthesia.

(3) Negroes were given larger doses of atropine (0.6-0.8 mg.) since they, too, seem to have greater tendency towards secretions. The value of the belladonna derivatives in preventing postoperative respiratory complications has been debated on many occasions. Opponents claim that increased viscidity of secretions results with tendency toward formation of plugs. DeTakats[10] has recently denied this, nor have we seen any harmful effects. Large doses of atropine have been shown to prevent reflex bronchoconstriction and bronchosecretion following intra-abdominal manipulations, such as traction on the cystic duct or on the mesentery.[10] Atelectasis has been reported occurring during surgery,[11] and it is possible that the reflex narrowing of bronchi together with increased secretions are predisposing factors in such instances. Atropine in larger than usual doses might therefore be justified as a prophylactic measure.

(4) Patients with chronic respiratory disease or irritation (bronchitis, bronchiectasis, heavy smokers, *etc.*) were urged to cough up the night's accumulation of secretions,[12] were placed later in the schedule so that this could be accomplished, and were even subjected to preoperative bronchoscopic aspiration if such measures as cough and postural drainage were insufficient in clearing the tracheobronchial tree. Wherever possible these patients were placed on the operating table in positions favorable for gravity drainage.[9]

The various mechanisms responsible for the elimination of secretions and fluids from the respiratory tract have been listed by Boyd, *et al.*[13] These include the ciliary mechanism, cough, the milking-like contractions of the bronchial muscles, the churning movements of breathing and reabsorption into the lymphatics and veins of the lung. These workers found the cilia capable of moving an amount of respiratory fluid considerably in excess of that normally present. In the presence of congestion or edema of the tracheobronchial mucosa, however, drainage was inadequate and secretions pooled in the lungs. So long as the experimental animals remained horizontal, relatively little respiratory fluid was eliminated. Tilting to 30°–50° head-down increased the drainage 30-fold:

| Tracheobronchial Mucosa: | *Intact* | *Congested & Edematous* |
|---|---|---|
| Animals at angle 0° | 3.2 cc./kilo/24 hrs. | 1.7 cc./kilo/24 hrs. |
| Animals at angle 30° | 3.5 cc./kilo/24 hrs. | 32.7 cc./kilo/24 hrs. |
| Animals at angle 50° | 3.6 cc./kilo/24 hrs. | 34.1 cc./kilo/24 hrs. |

This quantitative data clearly illustrates that respiratory disease is associated with accumulation of fluids, and that postural drainage is a valuable therapeutic measure in such instances.

(5) Oral hygiene was practiced, *i.e.*, correction of oral sepsis, use of mouth washes and brushing of teeth.[14]

B. *During Surgery.*—(1) The lightest plane of surgical anesthesia which was compatible with the task at hand was maintained. For example, during resection of the stomach, or during the anastomosis of the jejunum to the stomach in a gastric resection relatively light anesthesia sufficed. This was then increased during exploration, inversion of the duodenal stump, and closure. This substantially reduced the time required for postoperative awakening and the amount of anesthetic agent required. Many of the patients were awake before leaving the operating room.

(2) Anesthesia was stopped as a rule as soon as the peritoneum was closed. This permitted the patient to "blow-off" anesthetic agent, and also to fill his lungs with room air as respiration was stimulated by placing of the abdominal wall sutures. The presence of nitrogen in the alveoli is regarded as a prophylactic measure for collapse due to vascular absorption of readily absorbable mixtures high in oxygen content.[13]

(3) If patients with intestinal obstruction or gastric retention were operated upon under general anesthesia great care was taken to recognize any regurgitation of intestinal contents into the oropharynx. Although practically all of these patients had some form of suction-drainage prior to operation this was no guarantee against such an occurrence. When regurgitation was noted, immediate suction of the tracheobronchial tree was carried out through an endotracheal tube. Even in instances in which rather large amounts had been aspirated such a procedure was quite successful. These patients were bronchoscoped immediately after operation and the cleanliness of the respiratory passages was impressive. Tracheal suction can be instituted at once, before a bronchoscopist can be summoned, and is apparently quite effective. Regurgitation and aspiration can occur with any type of surgery, of course, but these complications can be anticipated more frequently in the presence of intestinal obstruction. We also employ cuffed endotracheal tubes in cases of intestinal obstruction to prevent aspiration, but occasionally fluid has slipped past even this barrier.

C. *Postoperative.*—(1) The patient was turned at least every hour. A radical change in position was insisted upon from the nursing staff.

(2) Secretions in the nose and mouth were aspirated by catheter as often as necessary.

(3) Inhalation of 100 per cent $CO_2$ was prescribed for 2–3 minutes

(unless no hyperpnea developed) every 20–30 minutes for six hours, then every hour for 24 hours. The $CO_2$ was delivered from a tank at the bedside through a rubber tube held six inches from the patient's face. This permitted the inhalation of a mixture of $CO_2$ in air rather than in oxygen, minimizing absorption of alveolar gases during the post-$CO_2$ depression of breathing. The rationale of this has been discussed by Waters.

The value of $CO_2$ inhalations is a controversial matter. King[16] treated 648 patients postoperatively with such inhalations, using another group of 667 individuals as controls. He was unable to demonstrate any decreased incidence of major pulmonary complications following $CO_2$. It should be pointed out, however, that the treated cases were divided into several groups: One breathed an increased $CO_2$ mixture for three minutes three times a day; another for 3–6 times a day, while another received such therapy 6–10 times a day. We feel that the chief value of such inhalations lies in the first six hours, and insist that our patients receive this treatment 2–3 times an hour during that period. King's cases, in our opinion, did not receive $CO_2$ therapy of sufficient intensity to prove or disprove its value.

A recent report by Mushin and Faux[17] is interesting along this same line. These workers demonstrated a decreased incidence of postoperative respiratory morbidity in a series of 24 patients placed in a respirator for the first 24 hours postoperatively. Since such a procedure ensured full respiratory movements, one can use such data to substantiate the belief that the respiratory stimulation caused by frequent exposure to $CO_2$ mixtures is valuable.

We propose to employ a similar approach by hyperventilating patients with a positive pressure technic soon to be described. Again, the virtue of full respiratory excursions (together with the increased speed of elimination of anesthetic agent) can be submitted to analysis.

(4) Narcotics were kept to a minimum and codeine sulfate was used whenever possible for the relief of pain. There were two reasons for this practice. First, we desired to maintain the cough reflex as active as possible. Second, morphine suppresses ciliary activity considerably, interfering with elimination of secretions from the respiratory tract.[18]

(5) The abdominal wall was supported whenever the patient could be made to cough. This was accomplished manually, and not with binders. Adhesive was limited to the maintenance of light gauze dressings.

(6) Aged individuals were mobilized as early as possible.[19]

(7) Intestinal suction tubes were removed early to avoid nasal and pharyngeal irritation with outpouring of secretions.

(8) Chemotherapeutic or antibiotic agents were administered prophylactically if respiratory morbidity was especially likely.

(9) We have only rarely attempted to improve ventilation by blocking painful impulses from the operative site. Starr and Gilman[20] describe an increase in vital capacity (23 per cent) following unilateral intercostal block in eight patients who had had biliary tract operations. This is worthy of further study, particularly if a safe, long-lasting local anesthetic can be discovered.

Johnson[21] appears to have minimized postoperative complications following pneumonectomy by crushing the intercostal nerves supplying the operative site.

(10) Finally, the problem of postoperative complications was placed squarely before the nursing staff as a challenge. They were instructed in the rationale of the "stir-up regimen";[22] they were praised for the successful management of difficult cases and shared in our concern when a complication arose.

With the institution of the program outlined above, the incidence of postoperative atelectasis and pneumonia following general anesthesia decreased from 11.0 per cent to 4.1 per cent, an incidence slightly lower than that seen after spinal anesthesia.

That these two methods of anesthesia should have a similar incidence of postoperative respiratory morbidity is not strange when one considers that regardless of the anesthetic technic the surgical patient's resistance is lowered to the same degree in each instance by his primary disease, the insult of surgery, exposure to drafty corridors and to the respiratory flora of attendants. It has been argued that the decreased ventilation associated with high spinal anesthesia (block of intercostal muscles) predisposes to atelectasis; and that as the patient awakens from an inhalation anesthetic, he tends to struggle, retch, move about and, hence, expand pulmonary alveoli more efficiently than the individual recovering from spinal. For these reasons some anesthetists expect a higher respiratory morbidity following this latter technic. Most reports, however, indicate no statistically significant difference.

The importance of the immediate postoperative care of surgical patients is being increasingly recognized. Lundy[23] describes a "postanesthetic room" staffed by personnel specially trained in the management of the unconscious patient, and fully equipped to handle all emergencies. These observation rooms should form an integral part of all surgical services, for they can almost certainly reduce postoperative morbidity and mortality.

III. *Anesthetic Agent.*—Table III presents the incidence of atelectasis and pneumonia following various general anesthetics. Analyzed statistically,

TABLE III

INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING GENERAL ANESTHESIA LISTED ACCORDING TO ANESTHETIC AGENT

| | Series I | | Series II | | Total | | |
|---|---|---|---|---|---|---|---|
| | Cases | Compl. | Cases | Compl. | Cases | Compl. | % |
| Ether | 84 | 8 | 232 | 10 | 316 | 18 | 5.7 |
| Cyclopropane | 6 | 2 | 23 | 3 | 39 | 5 | 12.8 |
| Cyclo. and curare or dihydro-B-erythroidin | 0 | 0 | 87 | 1 | 87 | 1 | 1.1 |
| Local and pent | 0 | 0 | 1 | 0 | 1 | 0 | |

there is no significant difference between the various drugs. The extremely low incidence of respiratory complications following the combination of cyclopropane and curare or dihydro-B-erythroidin deserves comment. A larger series of cases is required before definite conclusions can be reached, but it is highly suggestive that the use of an inhalation anesthetic to produce uncon-

sciousness and of another substance to produce muscular relaxation is a valuable technic as far as postoperative respiratory morbidity is concerned. The data also indicate that ethyl ether does not constitute the threat to the lungs which is assumed by many internists. The relatively high morbidity after cyclopropane alone is probably due to the fact that this agent was selected for individuals whose physical status was abnormal. These patients respond with an increased incidence of postoperative complications by the very nature of their debility.

IV. *Endotracheal Tubes.*—Table IV indicates the influence of an endotracheal tube on the development of atelectasis or pneumonia. Although the percentage of complications is greater in the presence of endotracheal technics,

TABLE IV

INCIDENCE OF ATELECTASIS AND PNEUMONIA FOLLOWING GENERAL ANESTHESIA LISTED ACCORDING TO USE OF ENDOTRACHEAL TUBE

| | Series I | | | Series II | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cases | Compl. | % | Cases | Compl. | % | Cases | Compl. | % |
| With tube..... | 69 | 9 | 13.0 | 234 | 10 | 4.3 | 303 | 19 | 6.3 |
| Without tube.. | 21 | 1 | 4.7 | 109 | 4 | 3.7 | 130 | 5 | 3.9 |

these data are not statistically significant. This agrees with the findings of other workers.[24, 33] In the presence of preëxisting upper respiratory tract infection endotracheal intubation may be followed by increased respiratory morbidity, but the value of this form of anesthesia is so great that when indicated it should not be withheld because of the hazard of a postoperative pulmonary complication.

V. *Age of Patient.*—In Table V are listed the number of cases according to age-groups, together with the percentage of respiratory complications and the statistical significance of the data.

TABLE V

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO THE AGE OF PATIENT

| Years | No. of Cases | Atel. and Pneum. | % | Significance |
|---|---|---|---|---|
| 1-20 | 22 | 2 | 9.0 | 0 |
| 21-30 | 129 | 6 | 4.7 | 0 |
| 31-40 | 213 | 5 | 2.4 | + |
| 41-50 | 296 | 18 | 6.1 | 0 |
| 51-60 | 355 | 19 | 5.3 | 0 |
| 61-70 | 180 | 11 | 6.1 | 0 |
| 71-80 | 32 | 6 | 18.7 | + |
| 81-90 | 4 | 1 | 25.0 | 0 |
| ? | 7 | 0 | 0 | 0 |

This relationship is perhaps better illustrated by a graph (Chart I).

It would appear that there was a period of maximal resistance in the age-group 31–40, with susceptibility increasing considerably in patients over 70 years of age. This has been noted by Taylor, *et al.*[6]

VI. *Sex of Patient.*—Table VI indicates the sex distribution in this series of cases. As has been pointed out before[2, 25] the incidence of pulmonary com-

plications is significantly higher in men than in women. Of all of the many reasons given for this sex difference the one which appeals to the authors is the suggestion of Ravdin and Kern[25] that women have a higher resistance to infections of the respiratory tract. A survey of comparable populations in an effort to demonstrate this point would be profitable. Other theories listed

TABLE VI

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO SEX

| | No. of Cases | Atel. and Pneum. | % |
|---|---|---|---|
| Male | 501 | 45 | 90 |
| Female | 739 | 25 | 31 |

include the greater incidence of smoking in men,[31] and the fact that respirations are more diaphragmatic in men and, hence, more affected by intra-abdominal surgery. Women seem more able to withstand pain. Could the difference in respiratory morbidity be due to the fact that men are more apt to splint respiratory muscles because of discomfort?

VII. *Duration of Operation.*—Table VII lists the incidence of atelectasis and pneumonia according to the duration of the surgical procedure. Again none of the data are statistically significant. It is interesting, however, that

TABLE VII

THE INCIDENCE OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA ACCORDING TO THE DURATION OF OPERATION

| Hours | No. of Cases | Atel. and Pneum. | % | Significance |
|---|---|---|---|---|
| 0-.5 | 14 | 0 | 0 | 0 |
| .5-1 | 346 | 14 | 4.0 | 0 |
| 1-1.5 | 329 | 15 | 4.6 | 0 |
| 1.5-2 | 212 | 14 | 6.6 | 0 |
| 2-3 | 227 | 11 | 4.9 | 0 |
| 3-4 | 85 | 9 | 10.5 | 0 |
| 4-5 | 20 | 4 | 20.0 | 0 |
| 5 | 7 | 1 | 14.3 | 0 |

respiratory morbidity does not begin to increase until after the third hour of surgery. Since many of the radical procedures for management of biliary tract obstruction, or intra-abdominal malignancy require a prolonged operative time this fact is reassuring. It should be recognized, however, that other surveys[6] indicate a linear relationship between the incidence of postoperative respiratory complications and duration of operation.

VIII. *Type of Operation.*—Table VIII indicates the relationship between the type of operation and the postoperative respiratory morbidity. Several facts are apparent from these data. First, gastric surgery, as a whole, is followed by the highest incidence of atelectasis and pneumonia. For example, Mimpriss and Etheridge[26] report 30 instances of atelectasis in a series of 100 consecutive partial gastrectomies. Second, emergency surgery or surgery upon ill patients is more of a hazard. This accounts in all probability for the increased incidence following cholecystostomy, cholecystenterostomy, gastro-enterostomy and

TABLE VIII

RELATION OF POSTOPERATIVE ATELECTASIS AND PNEUMONIA TO TYPE OF OPERATION

| Operation | General Anesthesia | | | | | | Spinal Anesthesia | | | | | | Spinal and General | | | | | | Total Series I and II | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Series I | | | Series II | | | Series I | | | Series II | | | Series I | | | Series II | | | | | |
| | Cases | Compl.* | % | Cases | Compl.* | % | Cases | Compl.* | % | Cases | Compl.* | % | Cases | Compl.* | % | Cases | Compl.* | % | Cases | Compl.* | % |
| Biliary Surgery: | | | | | | | | | | | | | | | | | | | | | |
| Cholecystectomy | 47 | 4 | 9 | 114 | 0 | 0 | 84 | 3 | 4 | 195 | 4 | 2 | 11 | 2 | 18 | 27 | 1 | 4 | 478 | 14 | 3 |
| Cholecystectomy and Choledochostomy | 2 | 0 | 0 | 22 | 1 | 5 | 20 | 0 | 0 | 70 | 2 | 3 | 2 | 0 | 0 | 8 | 1 | 13 | 124 | 4 | 3 |
| Cholecystostomy | 0 | 0 | 0 | 12 | 4 | 33 | 4 | 0 | 0 | 40 | 5 | 13 | 0 | 0 | 0 | 4 | 0 | 0 | 60 | 9 | 15 |
| Choledochostomy | 1 | 0 | 0 | 6 | 0 | 0 | 3 | 0 | 0 | 13 | 1 | 8 | 2 | 1 | 50 | 1 | 0 | 0 | 26 | 2 | 8 |
| Cholecystenterostomy | 2 | 0 | 0 | 5 | 0 | 0 | 4 | 1 | 25 | 5 | 1 | 20 | 1 | 0 | 0 | 3 | 0 | 0 | 20 | 2 | 10 |
| Plastic on common duct | 0 | 0 | 0 | 7 | 0 | 0 | 5 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 23 | 0 | 0 |
| Biopsy of gallbladder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 6 | 0 | 0 |
| Repair of fistula | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| Gastric Surgery: | | | | | | | | | | | | | | | | | | | | | |
| Resections | 22 | 4 | 18 | 85 | 6 | 7 | 15 | 2 | 13 | 48 | 4 | 8 | | | | 17 | 2 | 12 | 187 | 18 | 10 |
| Gastro-enterostomy | 5 | 2 | 40 | 10 | 1 | 10 | 4 | 0 | 0 | 9 | 1 | 11 | | | | 2 | 0 | 0 | 30 | 4 | 14 |
| Gastrostomy | 2 | 0 | 0 | 9 | 0 | 0 | 3 | 1 | 33 | 12 | 1 | 9 | | | | 0 | 0 | 0 | 26 | 2 | 8 |
| Repair of ruptured ulcer | 1 | 0 | 0 | 6 | 1 | 17 | 1 | 0 | 0 | 17 | 3 | 18 | | | | 4 | 0 | 0 | 29 | 4 | 14 |
| Polypectomy | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | | 0 | 0 | 0 | 3 | 0 | 0 |
| Pyloroplasty | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | | 0 | 0 | 0 | 2 | 0 | 0 |
| Upper Abdominal: | | | | | | | | | | | | | | | | | | | | | |
| Exploratory celiotomy | 4 | 0 | 0 | 24 | 0 | 0 | | | | 28 | 1 | 4 | | | | 8 | 0 | 0 | 64 | 1 | 2 |
| Exploratory celiotomy and biopsy or elysis of adhesions | 3 | 0 | 0 | 5 | 0 | 0 | | | | 15 | 0 | 0 | | | | 2 | 0 | 0 | 25 | 0 | 0 |
| Splenectomy | 0 | 0 | 0 | 11 | 1 | 0 | | | | 7 | 1 | 14 | | | | 7 | 1 | 14 | 25 | 3 | 12 |
| Ileotransverse colostomy | 1 | 0 | 0 | 2 | 0 | 0 | | | | 13 | 1 | 8 | | | | 5 | 1 | 20 | 21 | 2 | 10 |
| Other bowel surgery | | | | 4 | 0 | 0 | | | | 12 | 0 | 0 | | | | 3 | 1 | 33 | 19 | 1 | 5 |
| Pancreatic adenectomy or resection | | | | 7 | 0 | 0 | | | | 5 | 1 | 20 | | | | 0 | 0 | 0 | 12 | 1 | 8 |
| Transperitoneal nephrectomy | | | | 1 | 0 | 0 | | | | 2 | 0 | 0 | | | | 0 | 0 | 0 | 3 | 0 | 0 |
| Adrenalectomy | | | | 2 | 0 | 0 | | | | 0 | 0 | 0 | | | | 0 | 0 | 0 | 2 | 0 | 0 |
| I & D subdiaphragmatic abscess | | | | 3 | 0 | 0 | | | | 6 | 0 | 0 | | | | 0 | 0 | 0 | 9 | 0 | 0 |
| Marsupialization of liver cysts | | | | 0 | 0 | 0 | | | | 1 | 0 | 0 | | | | 1 | 0 | 0 | 2 | 0 | 0 |
| Splenectomy and nephrectomy | | | | 1 | 0 | 0 | | | | 0 | 0 | 0 | | | | 0 | 0 | 0 | 1 | 0 | 0 |
| Colectomy | | | | 4 | 0 | 0 | | | | 28 | 1 | 4 | | | | 7 | 0 | 0 | 39 | 1 | 3 |

* Compl. = Number of patients with atelectasis or pneumonia.

repair of ruptured ulcer. In the present series the incidence of atelectasis and pneumonia after cholecystectomy is low (3 per cent), as is that following partial gastric resection (10 per cent).

IX. *Economic Status of the Patient.*—It has been suggested[2] that the poorer classes of people are more likely to suffer from chronic respiratory tract diseases, particularly chronic bronchitis, and that it is this group which should

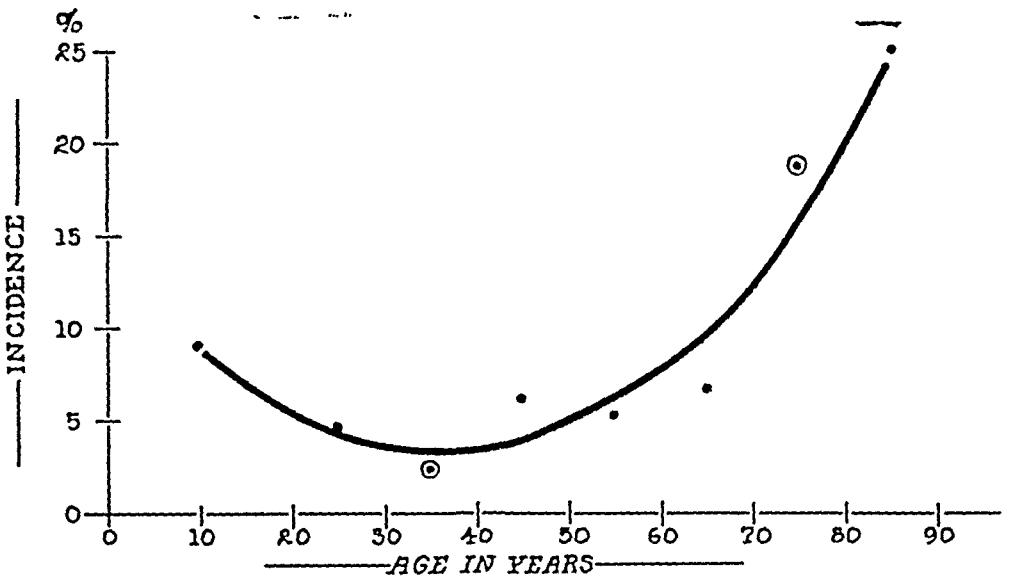



CHART I.—Relation of age of patient to incidence of postoperative atelectasis and pneumonia. (*The circled points are statistically significant.*)

show the highest incidence of postoperative atelectasis and pneumonia. Table IX is a study of the 1,240 cases divided according to their status as ward, semiprivate or private patients. We do not believe that this breakdown is a reflection of the original physical status of the patient. More likely explanations for the difference in incidence include the fact that most of the semiprivate and private patients had individual nurses caring for them, and had the benefit of surgeons of greater experience.

TABLE IX

THE INCIDENCE OF ATELECTASIS AND PNEUMONIA ACCORDING TO THE ECONOMIC STATUS OF THE PATIENT

| | Cases | Compl. | % |
|---|---|---|---|
| Private | 192 | 6 | 3.1 |
| Semiprivate | 395 | 13 | 3.5 |
| Ward | 653 | 50 | 7.7 |

## TREATMENT

Once the diagnosis of atelectasis was established certain definite therapeutic efforts were made. These varied with the degree of collapse. In the presence of massive or lobar collapse either tracheobronchial toilet, as described by Waters,[27] or bronchoscopic aspiration[32] was immediately instituted. The

advantage of the former method is that it can be carried out by the anesthetist who is readily available; it is an atraumatic procedure and an effective one. The activation of the cough reflex by stimulation at the carina removes secretions from the bronchioles even though the suction catheter does not reach the obstructing material directly. On the other hand bronchoscopy as performed at this hospital is also a relatively simple, bedside maneuver which we do not hesitate to employ. It is unfortunate that many clinicians feel such a valuable therapeutic tool to be too hazardous for the ill patient. This has not been our experience.

If patchy or lobular atelectasis was found, more conservative measures were attempted first. These included slapping the patient on the back vigorously with the flat of the hand, encouragement to cough with the operative incision well supported, and the introduction into the trachea of an urethral catheter passed nasally, according to the method of Haight.[28] A theoretic objection to this latter technic of tracheobronchial aspiration is that alveolar gases may be sucked out as the vocal cords close around the aspirating catheter. Thus, further collapse might result. This objection can be overcome by passing the aspirating catheter through a wide-bored endotracheal tube.

Finally, each patient with atelectasis was placed upon sulfadiazine or penicillin therapy to prevent development of bronchopneumonia.

In several recent articles other conservative approaches have been suggested. We have had no experience with these. They include administration of ascorbic acid in an attempt to decrease pulmonary capillary permeability,[29] the use of large doses of ammonium chloride as an expectorant to liquefy tenacious bronchial secretions together with ephedrine as a bronchial dilater,[30] and the use of postural drainage.[31]

Discussion.—The data presented in this paper serve merely to confirm other surveys of the relation of the anesthetic agent and method, the age, sex and economic status of the patient, and the duration and type of operation to the development of atelectasis and pneumonia in the postoperative period. We feel that our figures are of value for two reasons. First, they have been subjected to statistical analysis; and, second, they offer statistical evidence that general anesthesia is more likely to be followed by respiratory morbidity unless a rational prophylactic regimen is carried prior to surgery, during surgery and after surgery. There is, therefore, justification for the feeling of many clinicians that regional or spinal anesthesia is preferable from the standpoint of pulmonary complications. In hospitals in which unskilled anesthetic technic and unintelligent postoperative care characterize the management of the surgical patient such an opinion is sound. It must be emphatically pointed out, however, that such a sequence of events represents poor medical and surgical management. Our data, and those of other workers, conclusively demonstrate that the patient under general anesthesia need not anticipate a higher incidence of respiratory morbidity. Since many surgeons and many patients prefer this method of pain relief this point must be emphasized.

This survey lends impetus to the movement publicized by Lundy and directed towards the addition of an observation room to hospital facilities. Such a room will contribute materially towards a reduction in postoperative morbidity. Surgery has now reached a point where it can offer the patient an extremely low mortality rate. We are no longer as concerned with whether a patient will "come off the table." This is expected in the vast majority of operations. Rather, our concern is directed toward minimizing disturbance of function in such a way that the patient's operative and postoperative course is as smooth as possible. One's ultimate goal is that of minimal morbidity. For the respiratory tract this can be achieved only by attention to the details listed above. With surgeons preparing their patients more adequately for operation, with anesthetic skill available through the services of a specialist in this branch of medicine and with competent postoperative nursing in an observation room such a goal can be realized.

We also wish to urge more standardization in the diagnosis of atelectasis. In some English and Canadian reports it is difficult to avoid the conclusion that rather marked degrees of collapse are required before the condition is listed. Their classification of "chests" includes many instances of productive cough, fever and dyspnea which we feel are associated with patchy or lobular atelectasis. Criteria should be established so that data from various clinics can be more uniformly compared.

Should pulmonary embolus be included in a study such as this? There can be no doubt but that such a catastrophe must be classed as a respiratory complication. There is considerable doubt in our minds, however, as to whether intelligent management of the respiratory tract during surgery or postoperatively can affect the incidence of this complication. The occurrence of thrombophlebitis is related to the broad problem of anesthetic management, *e.g.,* poor position of the patient with resulting venous obstruction, low blood pressure with resulting thrombus formation, *etc.,* but these conditions do not involve the respiratory tract primarily and should be considered separately. The data of deTakats[10] which suggests that emboli may be the forerunner of certain cases of atelectasis in no way affects this reasoning. It is only by defining a condition clearly that one can subsequently define the problems requiring solution. Atelectasis and pneumonia fall into one group, embolus into another. To combine them invites confused thinking.

What are the problems of atelectasis? In this and other papers the clinical picture of atelectasis has been described. We find that the incidence is higher: (1) in men; (2) in smokers; (3) after surgery in the upper abdomen; (4) in patients with acute or chronic respiratory infections; (5) with increasing age; and (6) with increasing length of operation.

Faced with these clinical facts, various investigators have studied the respiratory tract, attempting to correlate alteration of function with bedside observations. Thus, a number of experimental facts have been equally well established. It can be stated with certainty that after abdominal surgery one can expect: (1) A sharp reduction in vital capacity;[35, 36, 37] (2) a decrease in sub-

tidal volume of the lungs;[38] (3) an elevation of the diaphragm;[4] and (4) a decreased excursion of the diaphragm.[4]

These mechanical changes produce hypoventilation of the lungs. The question is, does hypoventilation alone cause the clinical picture of atelectasis or must there be an additional factor, such as bronchial obstruction? If one could eliminate hypoventilation in the postoperative period by blocking painful impulses from the incision, by ensuring full respiratory movements with $CO_2$, a respirator or by positive pressure breathing, could atelectasis be prevented? We propose to test this hypothesis by forcing patients to ventilate under conditions of increased pressure within the respiratory tract.

If bronchial obstruction is found to be a requisite, there is another problem to be solved. Is atelectasis caused by absorption of alveolar gases behind an obstructing plug, or is the collapse secondary to the creation of negative pressure behind mucus moving up the bronchioles through ciliary action? This latter thesis has been advanced by Hilding[39] after a series of ingenious experiments.

Finally, there is the problem of reflex atelectasis. How important are the reflex bronchoconstrictor and bronchosecretory phenomena described by deTakats? What are the nerve pathways over which these reflexes are mediated and what can be done towards their prevention?

Once the relative importance of hypoventilation, secretions and afferent impulses is established one can hope for a further reduction in the incidence of postoperative atelectasis. With careful attention to theoretic and practical details, it is our opinion that this reduction in incidence can approach zero.

## SUMMARY

(1) The incidence of postoperative atelectasis and pneumonia in 1,240 cases of upper abdominal surgery is reported. The data are analyzed statistically from the standpoint of anesthetic agent and method, the age, sex and economic status of the patient, and the type and duration of operation.

(2) Factors concerned with the prevention of these respiratory complications are listed and a prophylactic regimen is outlined.

(3) Current theories as to the etiology of atelectasis are discussed and problems requiring further investigation are defined.

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# A TWO-STAGE MASTOPEXY IN PLASTIC SURGERY OF MARKEDLY ENLARGED BREASTS*

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OF NECESSITY, excessively enlarged breasts often require surgical help. Because of their marked size, a one-stage mastopexy is usually impractical to obtain the desired result. We have previously described the one-stage operation for reconstruction of enlarged pendulous breasts. However, when their size is of great proportions a two-stage procedure is desirable.

The purpose of the surgery is four-fold: (1) To obtain small breasts with reasonable size, shape, symmetry and contour. (2) To reconstruct two nearly identical breasts. (3) To obtain intact nipples and their areolae in the desired position. (4) To avoid loss of tissue following the surgery.

When breasts are of exaggerated size, the two-stage operation will meet all of these requirements and reduce variations to a minimum. Because such large breasts are usually functionless, the prime purpose of the operation is to obtain a small breast of the desired proportions. Suitable reconstruction of such enlargements cannot be accomplished with a one-stage mastopexy without danger of losing either portions or all of the nipple and skin flaps.

A two-stage operation, with transplantation of the nipple, may be utilized in such cases. We have described such a procedure but in our opinion the final result is not as satisfactory as the two-stage procedure, with transposition of the nipple.

## SURGICAL PROCEDURE

Under general anesthesia, the patient is placed on the operating table in a semisitting position with the arms akimbo. The operative area is prepared and suitably draped. The lines of incision are measured and marked with 3 per cent gentian violet solution (U. S. P.) The primary incision is a circle around the nipple areola usually measuring 48 mm. in diameter. From the center of the upper edge of this circle an incision is carried perpendicularly upward to within 12 mm. of the new nipple site. From the lower center of the circle an incision is carried perpendicularly downward to the inframammary line some four inches long forming an inverted "T" with the previous incision.

The skin over the whole breast is thoroughly undermined, forming two reasonably thick flaps. All bleeders are clamped and sutured with white No. 3–0 silk. The breast is entirely denuded of skin leaving the nipple and required amount of areola attached.

* Presented in conjunction with colored surgical motion pictures to the Riverside County Medical Society, Riverside, California, March 12, 1945 and the Los Angeles County Medical Society (Bay District Section) June 19, 1945.

FIG. 1-A

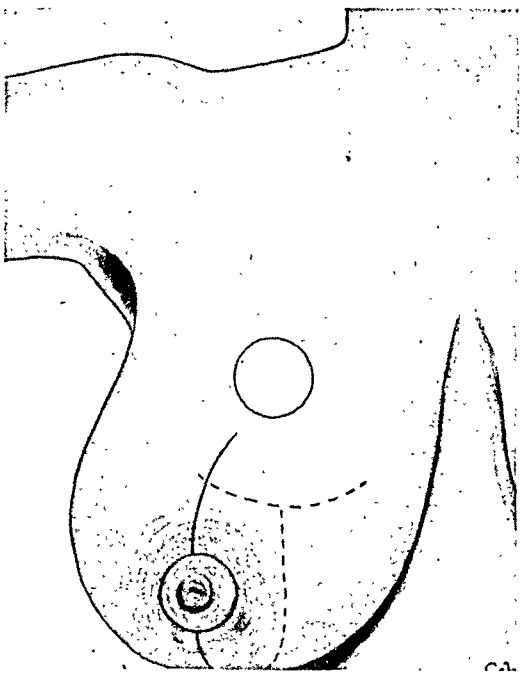
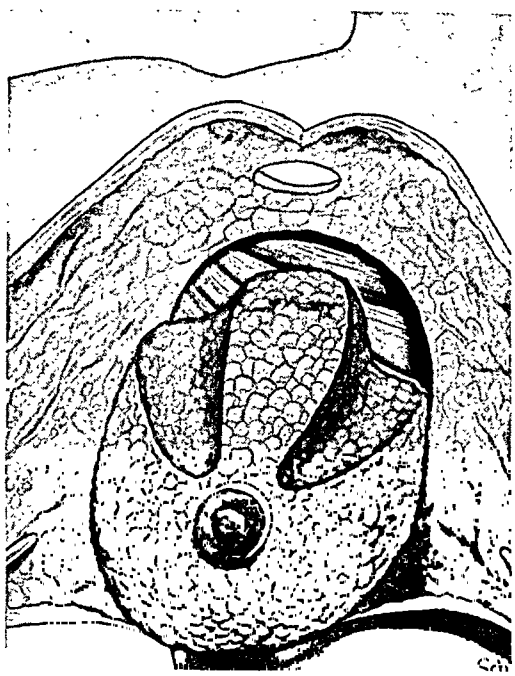


FIG. 1-B



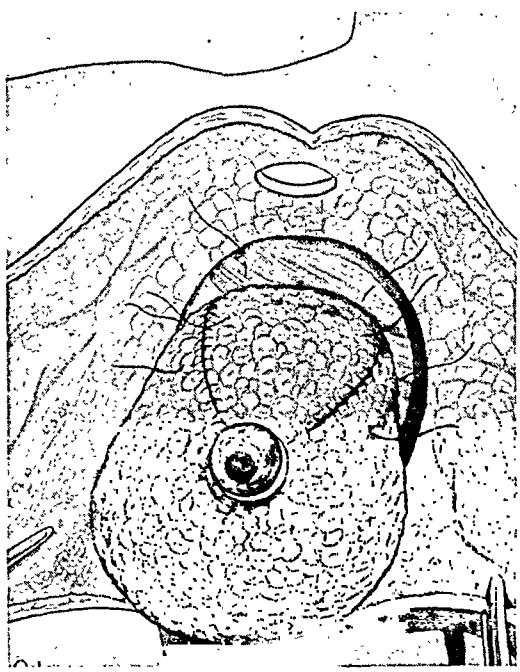


FIG. 1-C

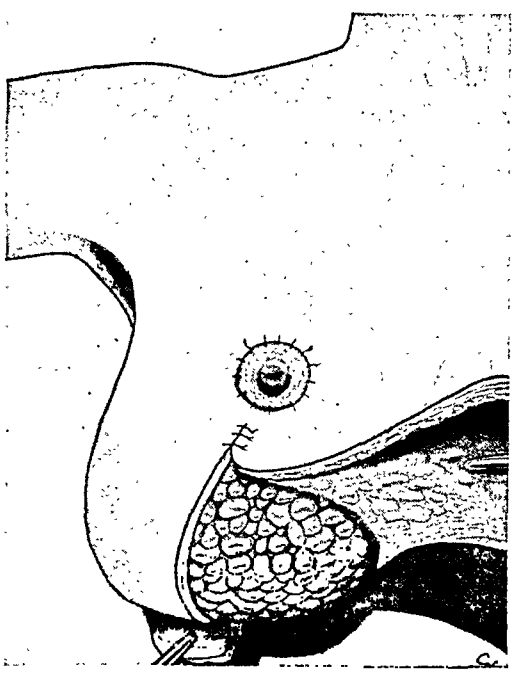


FIG. 1-D

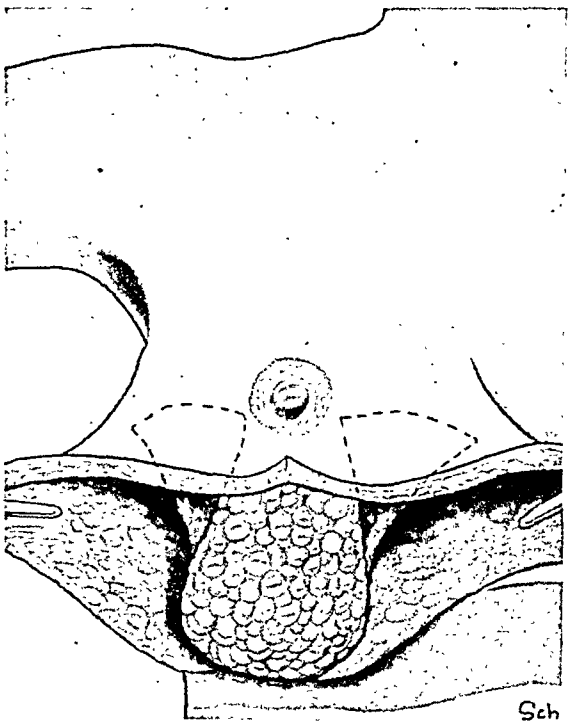
FIG. 1-A.—The incisions are measured and marked with 3 per cent gentian violet (U. S. P.) The lines of incision to form the flaps as well as the new residence for the nipple and the attached areola are meticulously marked.

FIG. 1-B.—The skin flaps have been dissected away, leaving the denuded breast with the required amount of areola and the nipple attached. The circular button of skin has been resected to receive the areola in its new position.

FIG. 1-C.—The walls have been sutured with silk. Four silk sutures (No. 4) are taken through the pectoral fascia over the second rib and passed through the upper pole of the breast to fix the latter in the desired position.

FIG. 1-D.—The areola has been carefully sutured to its new residence. The flaps are trimmed and temporarily sutured.

FIG. 1-E



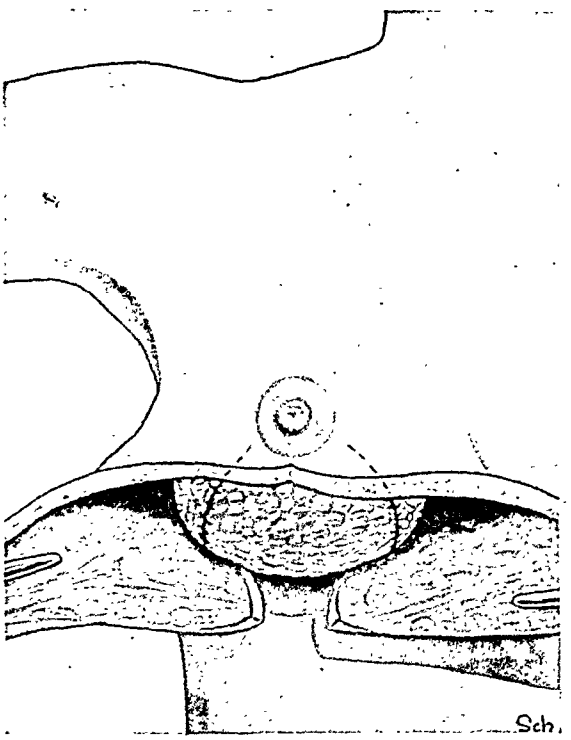




FIG. 1-F

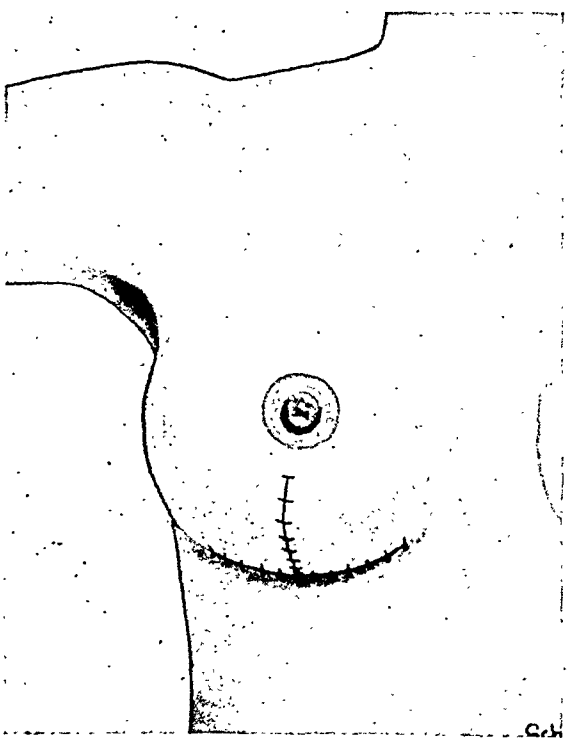


FIG. 1-G

FIG. 1-E.—Ten days to two weeks later the flaps are dissected free and two triangular wedges are resected from the lower pole of the breast.

FIG. 1-F.—The walls are sutured with silk and the flaps are trimmed and fitted to the contour of the newly constructed breast.

FIG. 1-G.—The operation has been completed. The flaps are sutured with interrupted silk sutures, resulting in an inverted "T."

Two triangular wedges of tissue are resected from the upper pole of the breast proper. The walls are approximated with No. 1 white silk. Four No. 4 silk sutures are taken through the pectoral fascia over the second rib, then through the upper pole of the breast, fixing the latter in the desired position.

A circle of skin is resected 12 mm. above the upper perpendicular incision and this serves as the new residence for the nipple and its attached areola. The latter is sewn into position.

FIG. 2-A FIG. 2-B FIG. 2-C



FIG. 2-D FIG. 2-E FIG. 2-F

FIG. 2-A.—Uniformly enlarged breasts with marked pendulousness.

FIG. 2-B.—Depicting the asymmetry between the two breasts and enlargement of the areolae.

FIG. 2-C.—The weight of the breasts has caused the patient to be round-shouldered with heavy shoulder strap marks in conjunction with poor general posture.

FIG. 2-D.—The two-stage mastopexy resulting in uniformly smaller breasts and areolae.

FIG. 2-E.—The breasts have been reconstructed to fit the patient and at the same time the excess weight and pendulousness have been eradicated.

FIG. 2-F.—The newly constructed breasts allow the patient to regain a more normal posture and eliminate her previous marked discomfort.



FIG. 3-A. — Enlarged breasts causing general debilitation, poor posture and deep shoulder strap marks.

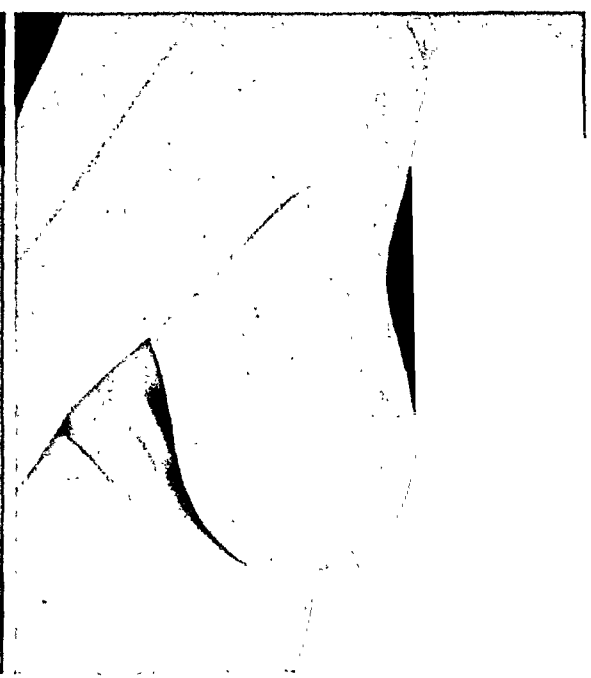


FIG. 3-B.—Breasts with such marked enlargement require a two-stage operation to obtain smaller breasts of the desired size, shape and symmetry.

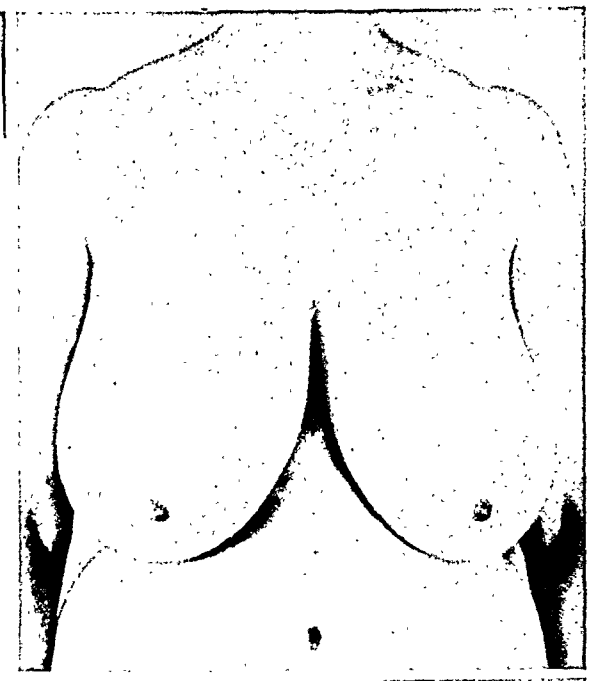


FIG. 3-C.—Depicting the marked enlargement, with the right breast larger than the left.



FIG. 3-D. — Six weeks following the two-stage mastopexy showing the inverted "T" scar. The latter fades quite appreciably with the passage of time.

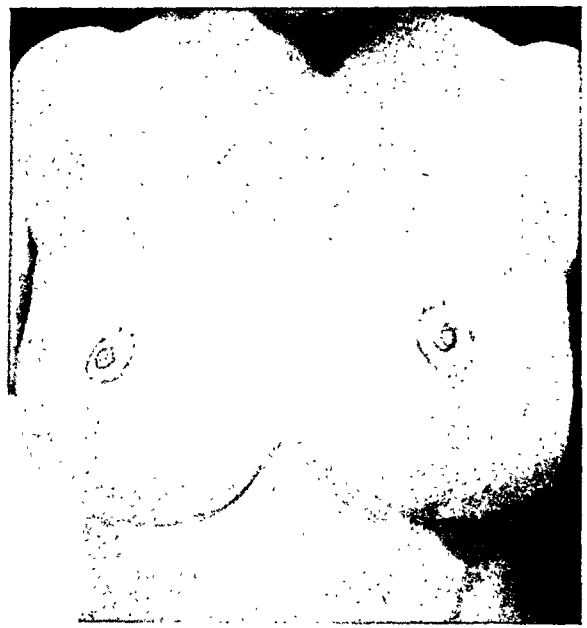


FIG. 3-E. — The breasts have been reconstructed to a uniformly smaller size, shape and contour.



FIG. 3-F. — The weighty pendulousness and marked discomfort have been eradicated.

The excess skin from both flaps is trimmed and the latter are temporarily sutured. A large Penrose drain is inserted upward through each corner of the inframammary incision.

A similar procedure is repeated on the opposite breast. Moderate pressure dressings are applied and the patient is returned to bed and placed in a semi-Fowler position.



FIG. 4-A



FIG. 4-B

FIG. 4-A.—Large pendulous breasts.
FIG. 4-B.—Reconstruction of the breasts in a two-stage mastopexy.

*Second Stage:* Ten days to two weeks later, the perpendicular incision below the nipple, as well as the inframammary wound are opened. The flaps on either side are easily separated, exposing the denuded lower poles of the breast. Two triangular wedges are resected from either side of the lower pole. The walls are approximated with white silk. Sulfanilamide crystals may be sprinkled into the wound. The two flaps on either side are trimmed to fit the contour of the reconstructed breast. If necessary the inframammary incision is lengthened slightly on each side. The skin is approximated with white silk (No. 4–0) subcutaneously and black silk (No. 4–0) interrupted in the skin. Two Penrose drains are placed upward through each corner of the inframammary incision.

A similar procedure is carried out on the opposite breast. Meticulous care is taken that both breasts are of equal size, shape and contour and that the lines of incision match in position and length.

A moderate pressure dressing is applied and the patient is returned to bed and placed in a semi-Fowler position.

SUMMARY

The method described allows for plastic reconstruction of excessively enlarged breasts with a minimum danger of losing any tissue. At the same time the procedure presents sufficient elasticity so that the surgeon may create small breasts of the desired proportions from an exaggerated deformity.

Gentleness in handling tissue, meticulous surgery, careful planning of the procedure and a knowledge of the surgical anatomy are presupposed.

# A MINUTE GRANULOSA CELL TUMOR, WITH VAGINAL BLEEDING

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IN SPITE of the intensive interest directed toward granulosa cell tumors in recent years this type of tumor is still a source of considerable speculation and controversy. Granulosa cell tumors are not considered uncommon any longer. They are found in 4 per cent of all ovarian neoplasms, and 21.4 per cent of all ovarian carcinomas. They occur at any age—48.7 per cent during the child-bearing period, 42.5 per cent after the menopause, and only 8 per cent in the prepuberal period. The majority of the cases present a clear-cut picture,—a tumor that is usually unilateral, and whose average size is that of an orange. Atypical menses, enlarged breasts and enlargement of the uterus usually occur, and 70 to 85 per cent show abnormal bleeding. Fifteen to 25 per cent of them are malignant; recurrence occurs in about 10 per cent, usually late (15 years in some cases). Symptoms and signs regress after removal of the neoplasm. The case presented, herewith, is unusual because it is such a small granulosa cell tumor to be associated with abnormal vaginal bleeding. Although 70 to 85 per cent of all granulosa cell tumors show biologic activity (abnormal bleeding and hyperplasia), tumors that are so small as to be mere collections of epithelial cells rarely are associated with biologic activity. As a rule, such collections are discovered in routine pathologic examinations, and have been designated *"granulosa-ballen,"* and, although they do not show any hormonal behavior, they are credited with being precursors of granulosa cell tumors. It is unusual to have such a long period of biologic activity as shown by the case herein presented, the patient having had irregular bleeding for nine years; such prolonged bleeding is a rarity even in fully developed tumors; the history of the average granulosa cell tumor gives indications of activity for only a matter of months to a few years. That the minute neoplasm in the case herein reported gave no evidence of growth during all these years is also uncommon, because records show that the size of the average granulosa cell tumor is somewhat in proportion to the amount and duration of its activity.

**Case Report.**—The patient had had three admissions to the hospital. On her first admission she was 14 years old. Her complaint was vaginal bleeding, spotting continuously for three months. Her periods had been normal since the menarche, six months prior to the onset of this episode of bleeding. Pelvic examination under anesthesia was entirely negative. A diagnosis of dysfunctional bleeding, puberal in type, was made.

On her second admission she was 21 years old. She came to the hospital because of profuse vaginal bleeding for one month. She gave a history of intermittent irregularity of her periods since puberty, but she never previously had such a persistent, profuse episode of bleeding, without pain.. Diagnosis of possible abortion was made. A curettage was done, but no pregnancy was found. Again, a diagnosis of hormonal bleeding was made.

On her third, and last, admission, again for vaginal bleeding, she was 23 years old.

She stated that she had bled continuously since her previous admission, about two years ago. Pelvic examination at this time showed a small mass in the left adnexal region. At operation, this was found to be a thickened tube wrapped around a normal-sized ovary. The tube and ovary were inseparable and, therefore, both removed, partial resection of the remaining tube was done. Microscopic examination of the ovary revealed the granulosa cell tumor.

*Microscopic Examination.*—Dr. Robert Meyer: "The small, rounded aggregation of epithelial elements represents the folliculoid type of granulosa cell tumor, with a very rare dissipation to some small nodules and single strands of cells of the same type in other parts of the ovary. They are lying partially in the hilum of the ovary and partially in the medullary part, with a few small nodules reaching into the cortex. The structure of this folliculoid tissue is the same as in the ordinary granulosa cell tumor. The cells are largely swollen and clear, due to lipoid deposition. In the portion lying in the hilum are some irregularly-shaped heaps and cords of epitheloid interstitial cells as well as single interstitial cells. In the same field some of the folliculoid parts are in such a degree of regression that only large disk-like droplets, the contents of former vacuoles, remain." (See illustrations).

Discussion.—Pelvic inflammatory disease as a cause of bleeding in our case is not tenable because she has had irregular vaginal bleeding since her menarche nine years ago—and evidence of pelvic inflammatory disease was absent even a number of months before operation.

The facts in this case—irregular bleeding since the menarche (nine years previously), cured by removal of an apparently normal ovary that harbored a small granulosa cell tumor 3 mm. in diameter, seem to indicate clearly enough the etiology of the disturbance. However, a careful evaluation was necessary in order to arrive at a proper conclusion, due to the vagaries of the dysontogenetic group of tumors and the paucity of cases reported under 1 cm., associated with biologic activity.

That numerous cases of dysontogenetic neoplasms should have been reported that do not follow the expected pattern of behavior is understandable because of the differences in interpretation. For instance, E. H. Norris,[10] believes a diagnosis is not justified by microscopy alone, and that pre- and postoperative endocrine studies are necessary (this is a very impractical procedure in most cases). Schiller,[12] on the other hand, believes that microscopic study should be the all-important criteria in their diagnosis, because clinical pictures can be confusing since ovaries can produce virilizing effects and testes can produce folliculin. Geist and Gaines[3] reported two cases with masculinizing syndromes in which they found scattered throughout the cortex and medulla numerous groups of large foamy cells distributed diffusely throughout the ovary in irregular strands and accumulations of varying sizes, but in neither case did removal result in regression of symptoms, so that these biologic changes could only have been secondary to changes in the pituitary or adrenals; similar changes could also be due to gonadtropins, as in hydatidiform mole or chorioepithelioma.

Robert L. Blackmun[1] reported a case of masculinization in which the ovary showed pathology similar to the cases reported by Geist and Gaines,[3] and operation in this case cured the patient. The pathologic picture in all these

FIG. 1

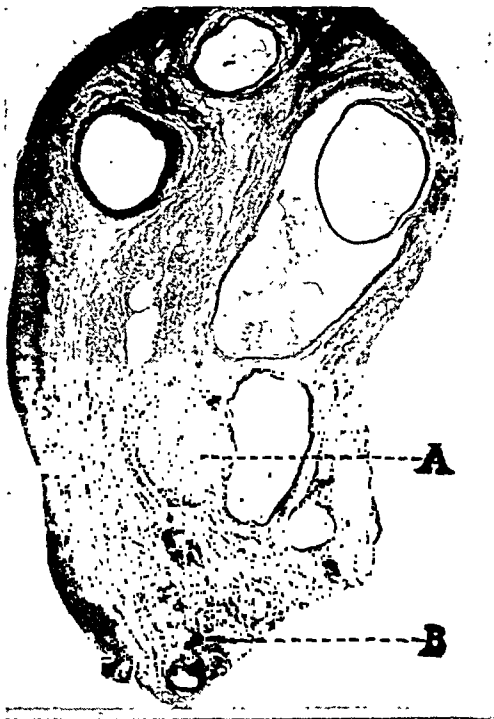
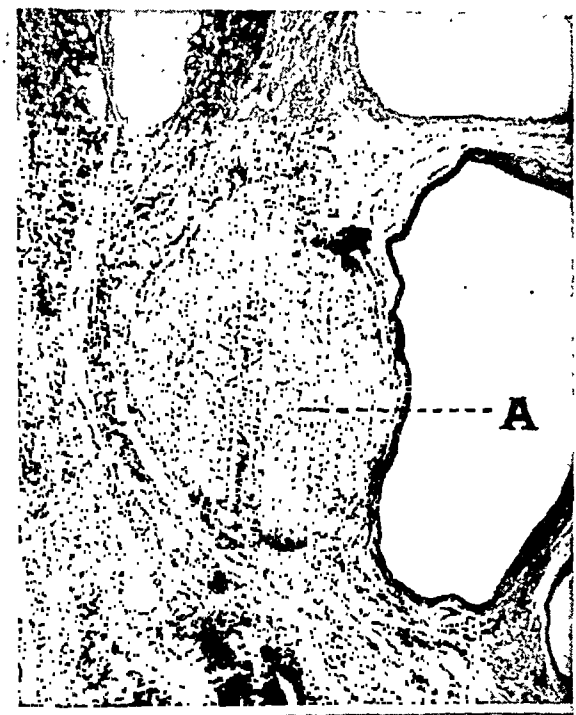



FIG. 2







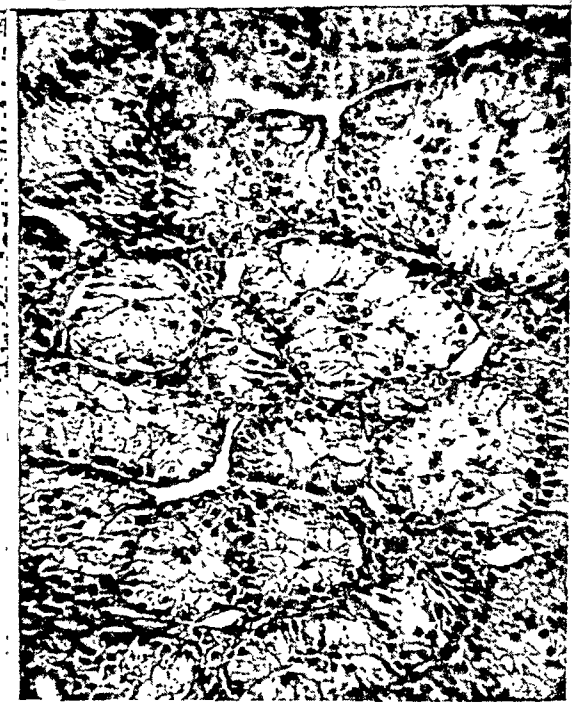


FIG. 3

FIG. 4

FIG. 1.—Low power photomicrograph of ovary, that measures 2.5 cm. x 1.5 cm. x 1.3 cm., showing (A) small granulosa cell tumor, 3 mm. in diameter. (B) Scattered collections of granulosa cells.

FIG. 2.—Higher magnification of (A) in Figure 1, showing the granulosa cell tumor.

FIG. 3.—Higher magnification of (B) in Figure 1, showing the scattered collections of granulosa cells near a follicle.

FIG. 4.—High power photomicrograph of granulosa cell tumor (A) in Figures 1 and 2, showing the folliculoid arrangement of the cells, swollen and clear due to lipoid deposition.

cases, superficially, was not unlike the one herein reported; in fact the slides (ovary with the small granulosa cell tumor) in the case here reported showed interstitial cells in the ovary, a finding usually associated with tumors of epithelial cells of male origin. Nelson Henderson,[6] in his study of 21 granulosa cell tumors, noted many variations in the behavior of these growths, and the statement of Novak[11] that some cases of biologic activity, such as precocity, are not due to granulosa cell tumors, but may be the result of some disturbance of the pituitary or adrenals, is further evidence of the diagnostic complexities of the dysontogenetic group of neoplasms.

The syndrome of the tumor herewith presented does not follow the pattern of any previously reported case. This does not mean that none exist. They do not come to our attention because we have never suspected them and so have not looked for them, probably because they occur in a normal-sized ovary. I have been interested in tumors occurring in normal-sized ovaries; a paper on this subject is now in the process of publication (Am. Jour. Obst. & Gynec.) (published in Am. Jour. Obst. & Gynec. Vol. 51, No. 2, Feb. 1946, p. 246.) which shows that if the suspicion of a neoplasm in a normal-sized ovary is kept in mind, some of them can be detected at operation by careful examination, which includes inspection, palpation, puncture and even incision of the ovary during operation. With this in mind, a special effort has been made to detect these neoplasms at every operation where an abdomen is opened and the ovaries are able to be examined. Because of this interest in tumors in normal-sized ovaries, seven neoplasms were discovered in apparently normal ovaries during the past three years, among them the granulosa cell tumor herein reported. It is possible that a granulosa cell tumor of this particular type could be the basis of some cases of functional bleeding. There are patients with so-called functional bleeding that do not fit into any prescribed category and do not respond to the theoretic plan of treatment adapted to correct certain physiologic endocrine imbalances. They do not come to operation as a rule because no evident pathology is found by clinical examination. The case herein presented was designated dysfunctional bleeding for nine years before its true nature was learned. Some cases of functional bleeding that do not respond to treatment are very apt to end up in artificial castration either by roentgen ray or radium, seldom by operation, so that no evidence of their true nature is ever obtained. The lesion in those patients with bleeding from a small granulosa cell tumor that might come to operation for some other reason could very easily be missed in the pathologic examination, and these cases would, therefore, probably be classified dysfunctional bleeding.

The very small granulosa cell tumor herein presented behaves in a general way like an ordinary granulosa cell tumor, but there are a number of differences, so that the entire syndrome may be a new one, perhaps a distinct type of granulosa cell tumor. Its histopathology is the same as an ordinary granulosa cell tumor; it causes abnormal bleeding; and a cure can be effected by its removal—characteristics common to the ordinary granulosa cell tumor. But it is different in that it is so minute and has not distorted or changed the size of the ovary, after nine years of activity. More of these cases of a midget granulosa

cell tumor syndrome may be discovered if such a possibility is remembered and search made for them. In some cases of intractable functional bleeding not traceable to any apparent cause, it might be a good plan to perform a celiotomy first instead of artificial castration by roentgen ray or radium, in order to examine the ovaries in search of such a tumor.

## SUMMARY AND CONCLUSIONS

A minute granulosa cell tumor, three millimeters in diameter, was found in a woman 23 years old, which produced abnormal vaginal bleeding ever since her menarche, nine years previously. She was cured by the removal of a normal-sized ovary that harbored the neoplasm, and her menses have remained normal since the operation four years ago.

Because of the peculiar symptom of abnormal vaginal bleeding for nine years, without apparent growth of the minute tumor, it is possible that we are dealing with a new variety of granulosa cell tumor. The syndrome of this "midget granulosa cell tumor" could be the basis of some of the unexplained cases of so-called functional bleeding.

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# STREPTOCOCCUS VIRIDANS SEPTICEMIA FROM VEGETATIONS IN FEMORAL ARTERIOVENOUS ANEURYSM

## REPORT OF A CASE CURED BY SURGICAL EXCISION OF THE ANEURYSM

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SUBACUTE *Streptococcus veridans* septicemia is a common complication of valvular heart disease. It also occurs frequently in congenital heart disease. Less commonly it results from vegetations within extracardiac arteriovenous communications. Until recently subacute bacterial endocarditis was almost invariably fatal though at the present time it appears that intensive and prolonged treatment with penicillin yields rather favorable results. Since the valvular pathology still exists, however, there remains the hazard of a recurrence of the same process. When the disease results from congenital heart disorder the problem of treatment has been much the same as in those cases arising from valvular heart disease. An exception is that group of cases in which the vegetations occur in some congenital fistula near the heart which can be extirpated surgically, for example, instances of vegetations in a patent ductus arteriosus. Since the first surgical cure, reported by Touroff and Vesell,[1] in 1940, it has been apparent that the source of the bacteriemia can be removed by surgery and a permanent cure obtained. Similarly, when vegetations within extracardiac arteriovenous communications give rise to *Streptococcus viridans* septicemia a permanent cure can be effected by excision of the aneurysm. Although a number of instances of such bacteriemia associated with arteriovenous aneurysm have occasionally been observed in the past, the first surgical cure was reported by Hamman and Rienhoff.[2] Their patient was a 35-year-old man, with an arteriovenous aneurysm of the external iliac vessels which had resulted from a rifle injury 17 years before. In 1942 Touroff, Lande and Kroop[3] recorded a second case, a 26-year-old man who had an arteriovenous and saccular aneurysm of the profunda femoris vessels resulting from a gunshot wound nine years previously. More recently, a third case has been reported by Lipton and Miller,[4] that of a Negro, age 27, who had a femoral arteriovenous aneurysm of 15 years duration, which also had resulted from an accidental gunshot injury. No other examples of cure of *Streptococcus viridans* septicemia by surgical removal of an arteriovenous aneurysm have come to our attention.

Acquired arteriovenous aneurysms are relatively uncommon in peacetimes, but occur quite frequently in time of war. It is not unlikely that the great increase in the number of such fistulae brought about by the present war may result in more cases of bacteriemia from infected vegetations within these lesions. Because of this and because of the small number of cases reported with

surgical cure, it is felt advisable again to call attention to this syndrome by reporting in some detail a patient in whom such a cure was effected.

**Case Report.**—The patient, a 26-year-old soldier, had enjoyed good health in the past, had had no serious illness except for three attacks of malarial fever during the past 14 months, no operations, and review of his systems was not remarkable except for recurrent attacks of tonsillitis. His past cardiovascular history was entirely normal. He was inducted into the Army in March, 1943. On December 21, 1944, in Leyte, after 18 months of duty in the Southwest Pacific Area, he received penetrating grenade fragment injuries in the right thigh, left arm, left chest, and left thigh from enemy action. There was considerable bleeding from the right thigh wound, but it was controlled with compression bandage. His wounds were débrided at a Surgical Portable Hospital and he was evacuated through channels to a numbered General Hospital. Here, about the 18th of January, he called the attention of the attending medical officer to a purring sensation in the right thigh which he had first noted the third day after injury. The classical signs of arteriovenous aneurysm were found. He was returned by air to the Zone of Interior and was admitted to the Vascular Center at the Mayo General Hospital on February 11, 1945.

The wounds had healed without difficulty. He had no symptoms except for a purring sensation in the right thigh and a little numbness along the mesial aspect of his knee. He complained of no edema, coldness, cyanosis, pain or weakness in the right lower extremity. Physical examination revealed the generalized yellowish color of the skin, commonly seen in patients who have had prolonged atabrine therapy. His sclerae were normal in color. There was nothing remarkable about the general examination. There was no tortuosity or thickening of the peripheral arteries, no evidence of cardiac enlargement; his heart sounds were normal and there were no murmurs. There was an abnormal pulsation over the course of the femoral vessels in the proximal third of the thigh associated with a continuous thrill and a loud continuous bruit which could be heard down to the knee and up into the right lower quadrant of the abdomen. The thrill and bruit could be obliterated by direct pressure over the femoral vessels about 15 centimeters below the inguinal ligament. With such compression the pulse rate slowed from 76 to 52 per minute and the blood pressure rose from 124/64 to 138/86. After atropinization the blood pressure changes with compression were of the same magnitude but the pulse rate decreased only eight per minute. The dorsal pedal and posterior tibial pulses were normal in both feet as was the venous filling time. In a room at 22° C. the skin temperature of the right toes varied from 19° to 20° and of the left toes from 21° to 21.5.° Reactive hyperemia, after five minutes of total arterial occlusion, and with the fistula completely compressed by digital pressure, began in the toes in 20 seconds and was complete and full in the right foot in 90 seconds. EKG was normal except for a QRS complex of 0.12 seconds duration. Roentgenograms showed no cardiac enlargement, the frontal area being 146 square cm. compared to a predicted frontal area of 143 square cm. for a man of his height and weight. The impression was held that he had a femoral arteriovenous aneurysm with collateral circulation adequate for surgical extirpation.

On March 1, 1945 the patient developed chills and fever which recurred in 48 hours and the diagnosis of malaria was confirmed by a blood smear which was positive for *Plasmodium vivax*. The chills and fever were readily controlled by atabrine therapy, the blood smears became negative and he left the hospital on furlough. He returned on April 5, 1945. He had had a recurrence of chills and fever associated with a sore throat shortly after he left the hospital and a week later had developed some abdominal soreness and a persistent mild diarrhea. Thinking that he had a recurrence of malaria he had taken atabrine but his symptoms had not been relieved. He had been confined to bed most of the three weeks of his furlough and had lost 16 pounds in weight. He had some anorexia. On admission to the hospital, there was some tenderness in the region of the transverse colon and his spleen was just palpable. His temperature was 102° F. on admission and

not higher than 99.2° F. during the next three days. Stool examinations revealed the ova of hook worm and *Endamoebae*. Appropriate treatment for these parasites resulted in prompt disappearance of his intestinal symptoms. Repeated blood smears were negative for *Plasmodia*. He continued to have fever (Fig. 1).

On April 11, 1945, he had a chill and a temperature rise to 100.3° F. The next day it rose to 102.4° F. Atabrine was discontinued on April 14, 1945, no malarial parasites having been found in blood smears since March 3, 1945. On April 16, 1945 he had a severe chill followed by a rise in temperature to 102.4° F. Three days later he had another chill with a temperature of 101.3° F. He complained of some pain and tenderness

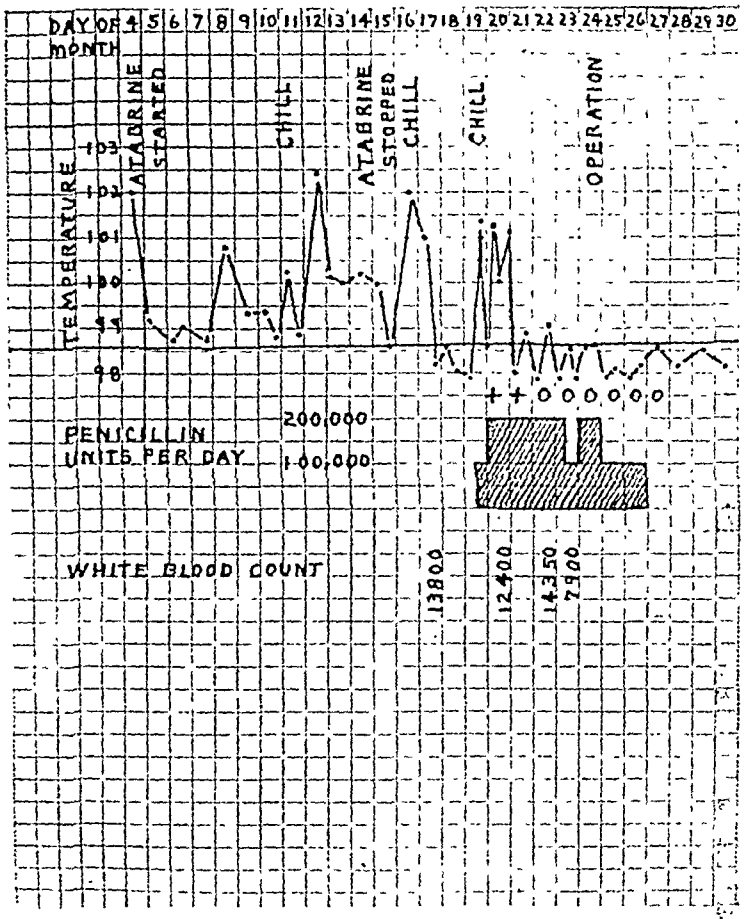



FIG. 1.—Temperature chart of patient preceding and following operation. The symbol + signifies a positive blood culture on the date indicated; the symbol O, a negative blood culture.

over the sternum and was dyspneic and orthopneic. Within a few hours the chest pain shifted laterally, being localized in the left fourth interspace in the anterior axillary line. There was marked tenderness here. For the first time a soft blowing nontransmitted systolic murmur was heard in the third interspace to the left of the sternum. The first heart sound was roughened and the apical impulse was displaced 3 cm. to the left of the midclavicular line. There were absent breath sounds, cripitant râles, and marked dullness to percussion over the left lower lobe posteriorly. Clinically, the findings suggested pulmonary embolism. The temperature was 101.2° F., the pulse 120, and respirations 20. Roentgenograms revealed increase in density obliterating the left lower lung field—findings compatible with a diagnosis of pulmonary infarction. The frontal cardiac area had increased from 146 sq. cm. on February 13, to 168 sq. cm. on April 5. On April 20, though difficult to measure because of the lung pathology, it was in the neighborhood of

174 sq. cm. EKG on the same day showed sinus tachycardia with slight slurring of QRS in the third lead and with a QRS complex of from 0.10 to 0.11 seconds duration.

The persistence of intermittent chills and fever, together with clinical and roentgenographic signs suggestive of pulmonary embolism, pointed to a diagnosis of septicemia, and it seemed most likely that the source was from infected vegetations within his arteriovenous aneurysm. A blood culture taken on the following day (April 20) was reported 24 hours later as positive for *Streptococcus viridans*. The white blood count was 12,400, with 28 per cent lymphocytes. Hemoglobin was 11.9 grams, prothrombin time was 30 seconds, and the hematocrit was 36. There was no increase in tenderness on pressure over the arteriovenous aneurysm and no petechiae were seen.

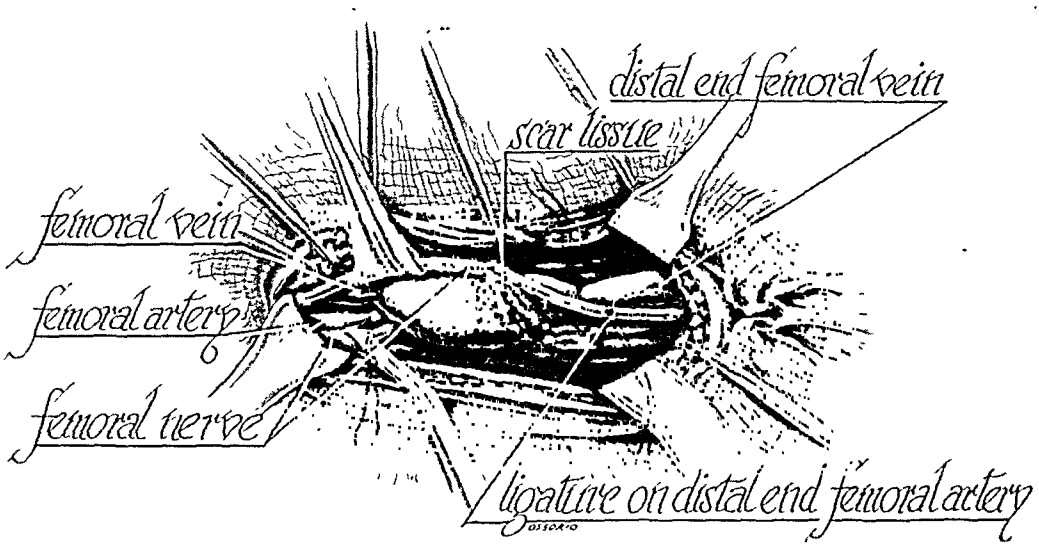



FIG. 2.—Drawing made from photograph of aneurysm taken during operation. The artery and vein have been ligated proximally and distally to the site of the fistula. The dilatation of the vein and the scarring in the region of the aneurysm are shown as well as the close association of the branches of the femoral nerve to the aneurysm. (Drawing by Cpl. Alfonso Ossario.)

The patient was acutely ill and his expression one of grave apprehension. He was given dilaudid for relief of his chest pain. Penicillin therapy was instituted on April 19 by the intramuscular injection of 25,000 units of penicillin sodium every three hours for three days, followed by 12,500 units every three hours for an additional three days. A second blood culture taken on April 21 was again positive for *Streptococcus viridans*. Subsequent blood cultures repeated on six consecutive days showed no growth of organisms. Coincident with the negative blood culture the patient became afebrile and free of chills. The white blood count dropped to 7,900, and his condition was much improved. Penicillin had apparently rendered the blood stream sterile in a period of less than 48 hours. On April 24, immediately after the intravenous injection of 100,000 units of penicillin, the patient was operated upon.

*Operation.*—Under spinal anesthesia, a longitudinal incision, about 12 cm. in length, was made over the course of the femoral vessels, beginning about 6 cm. below the inguinal fold. The fascia was divided and the sartorious muscle was retracted. There was a great deal of scarring in the region of the vessels. The femoral artery and vein were isolated above and below the fistula. The femoral vein was dilated to a diameter of about 2 cm. and the artery was about normal in size. A continuous thrill was present. The saphenous and the femoral nerves which were adherent to the vessels were dissected free without injury (Fig. 2). The artery and vein were divided above and below the fistula after

transfixing the stumps with silk. The wound was closed in layers with interrupted silk sutures. The patient's condition remained good during the operation.

*Pathologic Examination.*—Examination of the excised specimen revealed a large fistula, almost 1.5 cm. in diameter, between the artery and vein. The margins of the fistula were studded with small and minute vegetations (Fig. 3). Cultures taken directly from these vegetations, at a time when his blood cultures were negative, revealed a heavy growth of *Streptococcus viridans.* On microscopic examination these vegetations were literally studded with cocci (Fig. 4).

The patient's postoperative course was uneventful. He remained afebrile. The temperature and color of his right leg were normal. The bruit and thrill were no longer present. His pulse and blood pressure were normal. He was allowed out of bed on the 4th day. For some days he had a pulling sensation in his left chest on deep inspiration,



FIG. 4.—Photomicrograph of a portion of the specimen showing two bacteria-studded vegetations. (H. and E. stain.) On high power examination the dark staining areas are seen to be a mass of cocci. Culture of such vegetations as these yielded a pure growth of *Streptococcus viridans.*

but this discomfort rapidly disappeared. The dyspnea and orthopnea were gone. The signs of infarction in the left lower lobe gradually disappeared and six weeks after operation were absent by both radiologic and clinical examination. The size of his heart returned to normal (Fig. 5). The patient had at first a little edema of his leg after prolonged dependency. When examined on July 5 he stated that he had had no edema at all for a week. He was wearing an elastic stocking. He had no symptoms, except fatigue of his right lower extremity. On walking a distance of a half mile he would have a sense of fatigue in his calf. His feet showed no abnormal color changes. The posterior tibial and dorsal pedal pulses were normal on the left and were present, though reduced in volume, on the right. In a room at 25.5° C. there was no difference in the temperature of the toes of the right and left foot, all of the toes varying between 29 and 30° C. Oscillometry in the distal thigh was 2.5 at 70 mm. right, 6 at 120 left. In the calf it was 3 at 60 right, 7.5 at 90 left, and in the ankle it was 2 at 70 right and 5 at 80 left. His pulse was 56 and his blood pressure 128/70.

By the end of July the patient stated that he had practically no complaints at all. He had not worn elastic support for three weeks and had had no edema. He said that he

could walk an indefinite distance. After walking about a mile and a quarter he had a mild sense of tightness in his right calf, but the discomfort was not great enough to make him cease walking. There had been no recurrence of fever, chills nor of pulmonary or cardiac symptoms. He appeared to be in excellent general health.

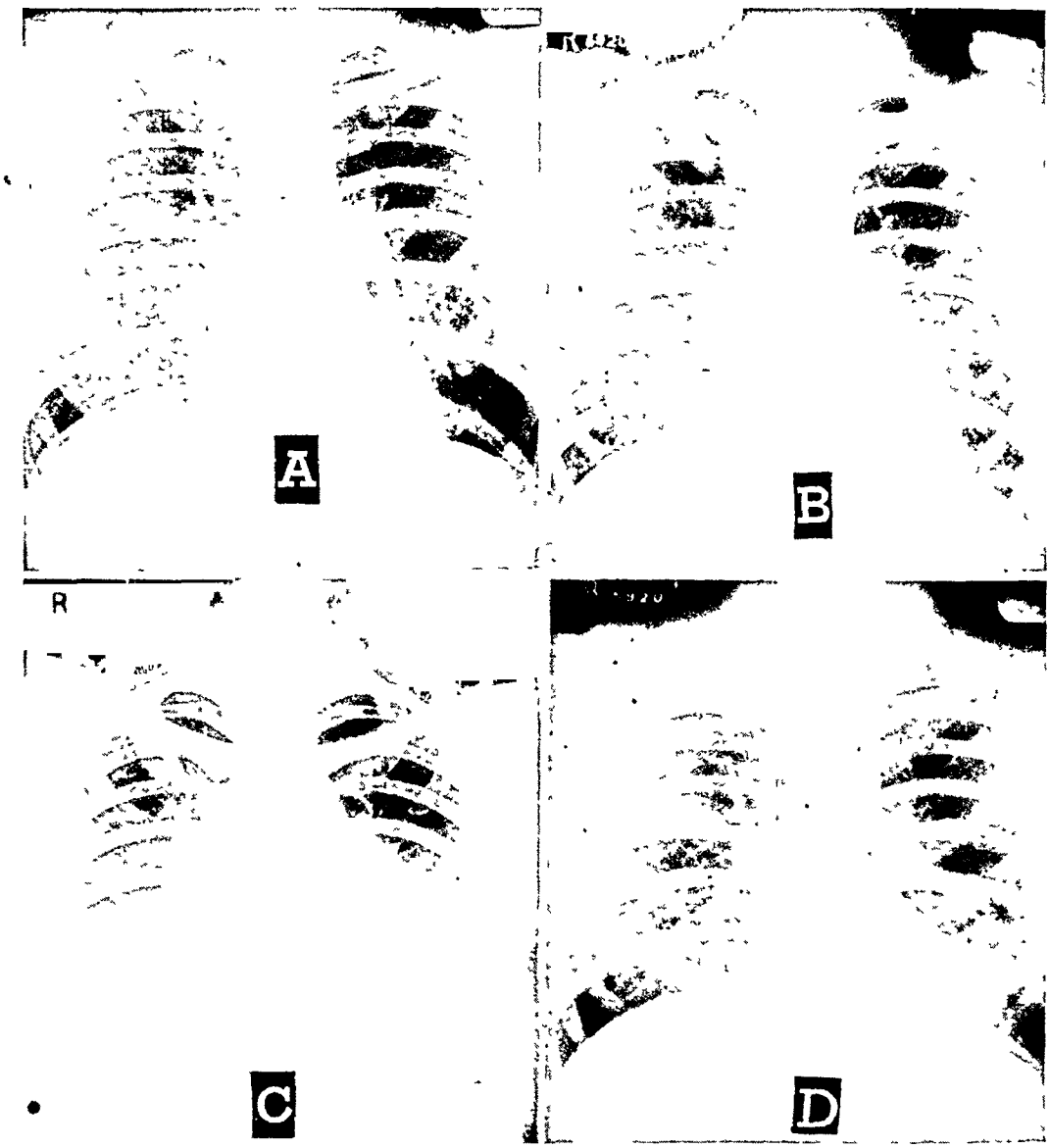



FIG. 5.—Roentgenograms showing change in heart size and the evidence of pulmonary infarction. (A) Roentgenogram taken February 13, 1945. Heart size is normal, the frontal cardiac area being 146 sq. cm. Predicted frontal area for a man of the patient's height and weight is 143 sq. cm. The method of Ungeleider and Gubner was used in computing heart size. (B) Roentgenogram taken March 1, 1945. Heart size has increased. Frontal cardiac area 168 sq. cm., 17 per cent above normal. (C) Roentgenogram taken April 23, 1945. The increased density in left lower lung field from pulmonary infarction is shown. Heart size difficult to estimate because of lung pathology and elevation of diaphragm. (D) Roentgenogram taken June 4, 1945. Postoperatively, the lung field has cleared and the heart size has returned to normal.

DISCUSSION.—It is a well-known fact that transient *Streptococcus viridans* bacteriemia occurs not rarely during upper respiratory or sinus infections and following extraction of infected teeth. Presumably such transient bacteriemia is the original source of infection in cases of subacute bacterial endocarditis and in instances similar to the case reported. It is of interest that our patient gave a history of recurrent attacks of tonsillitis since childhood and that he had had an attack of tonsillitis and pharyngitis, associated with chills and fever approximately a month prior to the diagnosis of septicemia. It is possible that this may have resulted in infected vegetations within his arteriovenous aneurysm.

The case reported is of considerable interest in regard to multiplicity of diseases from which the patient suffered during the course of his hospitalization. In addition to an attack of tonsillitis and pharyngitis, and the subsequently proved *Streptococcus viridans* septicemia, he had malarial fever, hook worm and *Endamoebae* in his stools. The fact that this patient had had recurrent episodes of malarial fever did not, however, delay long the diagnosis of *Streptococcus viridans* septicemia. The severe chills, the fever, the signs and symptoms of pulmonary infarction, the positive blood cultures and the presence of an arteriovenous aneurysm made the diagnosis relatively easy. The rapid increase in cardiac size is very likely directly the result of the altered circulatory dynamics consequent to the presence of a large femoral arteriovenous aneurysm. In other patients with similar lesions, rather marked increase in heart size has not been uncommon during the period of observation prior to excision of the aneurysm.

The case reported serves as another example of the necessity of bearing in mind the presence of arteriovenous aneurysm when looking for the source of infection in instances of *Streptococcus viridans* septicemia. It also exemplifies the dramatic cure which can be achieved in such instances by surgical removal of the aneurysm. Our patient was treated for a period of six days with penicillin, which apparently rendered the blood stream sterile prior to operation. That a permanent cure had not necessarily been obtained by this brief period of treatment is evident from the fact that the vegetations within the aneurysm yielded a heavy growth of *Streptococcus viridans.*

SUMMARY

A case is added to the three previously recorded in the literature of instances of cure of *Streptococcus viridans* septicemia associated with infected vegetations within peripheral arteriovenous aneurysms by surgical excision of the lesion.

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# THE INFLUENCE OF A SPECIAL HIGH PROTEIN DIET ON PROTEIN REGENERATION IN THE SURGICAL PATIENT*

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IT HAS BEEN ESTABLISHED[1, 2, 3] that negative nitrogen balance usually occurs in the postoperative patient. This has been correlated with loss of weight, prolonged wound healing, and extended convalescence.[4, 5] During recent months a great deal of investigation has been done in an attempt to institute positive nitrogen balance in these patients. The work of Co Tui, Elman, Rasmussen, particularly among others, is to be noted.[6-10] It is significant that amino-acid mixtures, plasma, and whole blood transfusions have been emphasized in these studies; the value of these we leave unquestioned. Most of the emphasis on protein replacement therapy in the surgical patient has centered around a substance that can be given safely by the intravenous route. In the studies reported here, we have thought it desirable to shift this emphasis to a diet that could be given orally, and to determine the value of an inexpensive protein material which can be made readily available to surgical patients. Despite the unsettled state of controversy that has revolved around the question of whether or not administered protein is assimilated during the catabolic phase which follows early after traumatic injury or surgical operation, we have supplied this diet to our patients soon after surgical operation.

## MATERIAL AND METHODS

Suitable surgical patients were selected; the dietary period was started on the 3rd to the 20th postoperative day. Nine patients, fully studied, are considered in this report, and clinical summaries of several illustrative cases are given.

A diet was made up as follows: 150 Gm. of dehydrate beef and liver protein mixture,† 150 Gm. of powdered whole milk, 50 Gm. of corn oil, 150 Gm. of sucrose, 150 Gm. of dextrimaltose, 35 Gm. of chocolate, 1,000 cc. of water (plus vitamins, especially A, B, C, and D, and Iron). This allowed a total intake of at least 3,000 calories for each 24-hour period.

The diet was administered in liquid form containing the insoluble materials

* This study was carried out in part under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development, and The Medical College of Virginia. It was supported by a liberal research grant to the Department of Biochemistry by Charles C. Haskell and Co., Richmond, Va.

† "Valentine High Protein Mixture" generously supplied by The Valentine's Meat Juice Company, Richmond, Va.

that had been put into a finely divided suspension by rapid stirring in a Mix-Master stirring machine. Since there was a tendency for this suspension to settle out with standing it was shaken before each feeding. In three cases tube feeding was resorted to during the first two or three days and thereafter the diet was taken readily by mouth. Frequent feedings throughout each 24-hour period were employed.

Blood volume, total and fractional plasma protein, hematocrit, and hemoglobin determinations were carried out at the beginning of each experiment, three or four days thereafter, and again at the end of the experimental period. The nitrogen content of the diet per cubic centimeter was determined and the protein intake for each day calculated from the volume administered. Daily urinary and fecal nitrogen excretion was determined and the nitrogen balance calculated. Blood volume studies allowed total circulating plasma and protein hemoglobin to be estimated. Each patient was studied for at least seven days.

## DISCUSSION OF RESULTS

Two cases (L. D., Chart 1; and T. H., Chart 2) of partial gastric resection and perforated peptic ulcer were given the diet starting on the 4th and 9th postoperative day, respectively. Both of these cases were uncomplicated and noninfective and both completed the feeding schedule without incident. In the case of L. D., the average nitrogen intake 24 hours was 23.5 Gm., with the average daily excretion being 19.7 Gm. of nitrogen. Studies of this case over an eight-day period revealed 81 Gm. of hemoglobin, and 39 Gm. of plasma protein formed to approximately 80 Gm. of tissue protein laid down. Average daily nitrogen excretion in the case of L. D. was very high as compared with the case of T. H. who was given the diet over a seven-day period. The latter case manifested an average daily nitrogen intake of 23.2 Gm., with an average daily excretion of 16.5 Gm. of nitrogen. Protein regeneration, however, was similar in distribution being of the order of 102 Gm. of hemoglobin, 44 Gm. of plasma protein, and with 160 Gm. of tissue protein being laid down. In respect to plasma protein formation, the case of T. H. showed the greatest gain in albumin fraction. It is to be noted that in the latter case, plasma protein concentration remained fairly low as shown by the values of 5.69 Gm. protein per 100 cc. plasma to 5.52 Gm. protein per 100 cc. plasma; yet the total circulating plasma protein gained considerably (Table I). Case summaries of both of these patients are presented below.

In the case where most intolerance to the diet was anticipated, that of G. B., (Chart 3) an abdominal gunshot wound with resection of eight feet of small bowel (ileum), the least difficulty was encountered. The diet was instituted on the 7th postoperative day and maintained for ten days. This patient responded exceedingly well, as shown by the regeneration of 70 Gm. of hemoglobin, 28 Gm. of plasma protein, and approximately 614 Gm. of tissue protein. Nitrogen retention in this case was over half of the calculated intake and demonstrates in this patient a remarkable power of assimilation in spite of the large amount of small bowel resected (see case summary).

Infective postoperative cases presented the greatest intolerance to the diet. These patients exhibited a great deal of anorexia, nausea, and vomiting, and only three cases are included where complete studies were made. These patients were given the diet by way of a Levine tube during the first 24 to 36 hours of feeding.

## PRESENTATION OF CASES

**Case** L. D. (Chart I): This 34-year-old colored male was admitted to St. Philip Hospital, March 2, 1944, with a chief complaint of severe progressive abdominal pain of 11 hours duration. The patient was quite nauseated but did not vomit.

CHART 1

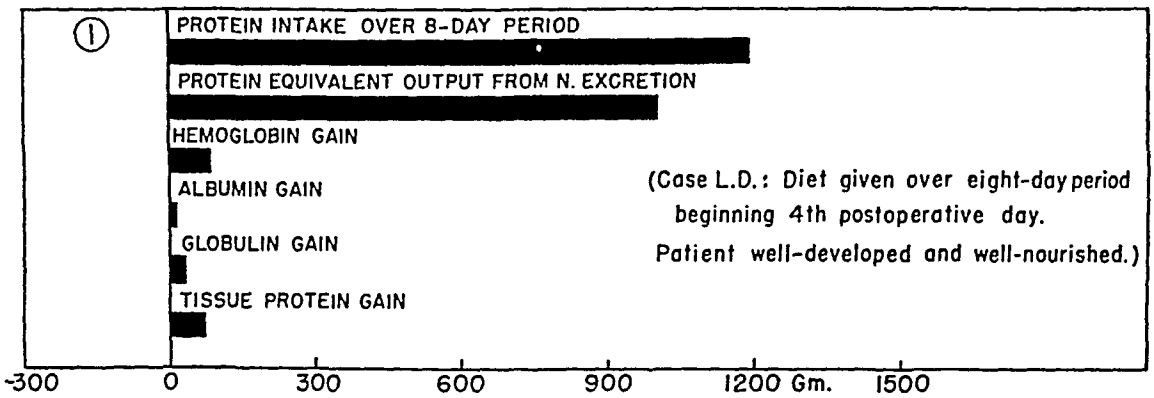



CHART 1.—Case L. D.: Nitrogen Balance Chart.

The diet was given over an eight-day period beginning on the 4th postoperative day. The patient was well-developed and well-nourished.

Physical examination revealed the abdominal wall rigid, especially over both upper quadrants. The patient was immediately taken to the operating room and, under spinal anesthesia, a right rectus incision was made. A moderate amount of creamy, thick, light yellow material was encountered. No odor to this material was apparent. The stomach was moderately distended, and a 2x2 cm. area of induration was found in the anterior, prepyloric region which was bound to the liver by fresh adhesions. Exploration revealed a perforation, of about 3 mm. in diameter, within this area. The ulcer area was partially excised and then closed with two rows of No. 1 B. S. S. The omentum was then caught up over the suture line and a third row of stitches was placed. The upper portion of the abdomen was then washed with warm saline and eight grams of mixed sulfonamide powder dusted over the area. The abdomen was then closed. The patient completed the operation in good postoperative condition. Laboratory studies on admission revealed the following: Hb. 73 per cent; W. B. C. 13,150, polys. 88 per cent. Urinanalysis was essentially negative. On the first postoperative day the Hb. 65 per cent; W. B. C. 10,500, polys. 70 per cent. On the 12th postoperative day the Hb. 82 per cent; W. B. C. 8,200, polys. 71 per cent. Two blood transfusions of 500 cc. each were given on the second postoperative day. The patient's temperature spiked on two occasions to 103° F., but began to recede on March 6, and thereafter varied between normal and a low grade fever until March 20. Chest roentgenograms during this interval revealed densities compatible with postoperative atelectasis in the right lower lobe. The condition of the patient, clinically, was good and severe infection did not appear to be present. The patient was given a special experimental diet over an eight-day period beginning on the 4th postoperative day (March 6). Nitrogen balance studies were carried out during the feeding period and the results tabulated. The patient was discharged March 23, 1934, and followed by the Out-patient Clinic.

TABLE I

SUMMARY OF RESULTS

| Case No. | Prot. Intake /Kilo. /24 hr. Gm. | N. Intake Gm. | N. Output Gm. | Blood Volume Init. Cc. | Blood Volume Final Cc. | Plasma Volume Init. Cc. | Plasma Volume Final Cc. | Plasma Albumin /100 Cc. Init. Gm. | Plasma Albumin /100 Cc. Final Gm. | Total Plasma Albumin Init. Gm. | Total Plasma Albumin Final Gm. | Alb. Gain Gm. | Plasma Globulin /100 Cc. Init. Gm. | Plasma Globulin /100 Cc. Final Gm. | Total Plasma Globulin Init. Gm. | Total Plasma Globulin Final Gm. | Glob. Gain Gm. | Average Hematocrit Reading Init. | Average Hematocrit Reading Final | Hemoglobin /100 Cc. Blood Init. Gm. | Hemoglobin /100 Cc. Blood Final Gm. | Total Hemoglobin Init. Gm. | Total Hemoglobin Final Gm. | Hemoglobin Gain Gm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L. D. | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-day period | 2.76 | 187 | 147 | 5,187 | 5,276 | 2,826 | 2,755 | 3.50 | 3.98 | 99 | 110 | 11 | 2.95 | 4.0 | 83 | 112 | 29 | 45.1 | 47.8 | 14.4 | 15.7 | 747 | 828 | 81 |
| T. H. | | | | | | | | | | | | | | | | | | | | | | | | |
| 7-day period | 2.39 | 162 | 116 | 4,798 | 6,000 | 3,242 | 4,125 | 3.49 | 3.66 | 113 | 151 | 38 | 2.2 | 1.86 | 71 | 77 | 6 | 30.5 | 31.3 | 9.36 | 9.18 | 449 | 551 | 102 |
| G. B. | | | | | | | | | | | | | | | | | | | | | | | | |
| 10-day period | 2.44 | 243 | 131 | 4,320 | 4,913 | 2,731 | 2,992 | 3.99 | 4.17 | 109 | 125 | 16 | 2.52 | 2.68 | 69 | 80 | 11 | 36.7 | 39.1 | 11.2 | 11.3 | 484 | 554 | 70 |
| J. H. | | | | | | | | | | | | | | | | | | | | | | | | |
| 1st 5 days | 3.77 | 119 | 45 | 4,633 | 4,874 | 3,068 | 3,184 | 3.75 | 4.0 | 115 | 128 | 13 | 2.68 | 2.66 | 82 | 85 | 3 | 33.8 | 34.7 | 10.8 | 11.0 | 492 | 538 | 46 |
| J. H. | | | | | | | | | | | | | | | | | | | | | | | | |
| 2nd 5 days | 3.77 | 108 | 57 | 4,874 | 4,621 | 3,184 | 3,074 | 4.0 | 3.86 | 128 | 119 | —9 | 2.66 | 3.13 | 85 | 96 | 11 | 34.7 | 33.5 | 11.0 | 10.6 | 538 | 490 | —48 |
| B. A. | | | | | | | | | | | | | | | | | | | | | | | | |
| 7-day period | 2.36 | 162 | 76 | 5,982 | 4,623 | 3,569 | 3,292 | 2.64 | 3.29 | 94 | 108 | 14 | 3.32 | 3.68 | 118 | 121 | 3 | 40.3 | 38.8 | 13 | 12.2 | 778 | 564 | —214 |
| M. P. | | | | | | | | | | | | | | | | | | | | | | | | |
| 7-day period | 2.99 | 184 | 51 | 3,349 | 3,594 | 2,472 | 2,543 | 3.66 | 3.24 | 90 | 83 | —8 | 3.53 | 3.40 | 87 | 86 | —1 | 22.9 | 28.9 | 6.3 | 8.34 | 211 | 300 | 89 |
| C. T. | | | | | | | | | | | | | | | | | | | | | | | | |
| 10-day period | 3.33 | 249 | 86 | 3,342 | 3,692 | 2,325 | 2,428 | 3.36 | 3.37 | 78 | 82 | 4 | 5.35 | 5.05 | 124 | 123 | —1 | 34.4 | 34.2 | 11.7 | 11.8 | 391 | 436 | 45 |
| J. W. | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-day period | 3.5 | 214 | 104 | 3,959 | 4,140 | 2,146 | 2,153 | 4.31 | 3.84 | 92 | 83 | —9 | 3.04 | 3.58 | 65 | 77 | 12 | 45.8 | 48.0 | 14.9 | 17.1 | 593 | 708 | 115 |

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**Case** T. H. (Chart 2) : This 43-year-old colored male was admitted to the hospital, February 8, 1944, following a profuse gastric hemorrhage. His chief complaint was hematemesis and tarry stools. History of the present illness dated to four years before at which time the patient began altering his diet because of indigestion. Following a night of beer drinking, February 5, he had a severe diarrhea. A large dose of Epsom salts was taken. On February 7, his stools were tarry black. On the night of admission, he experienced an episode of faintness and sweating. He vomited about one-half cupful of bloody clots and coffee ground-like material.

CHART 2

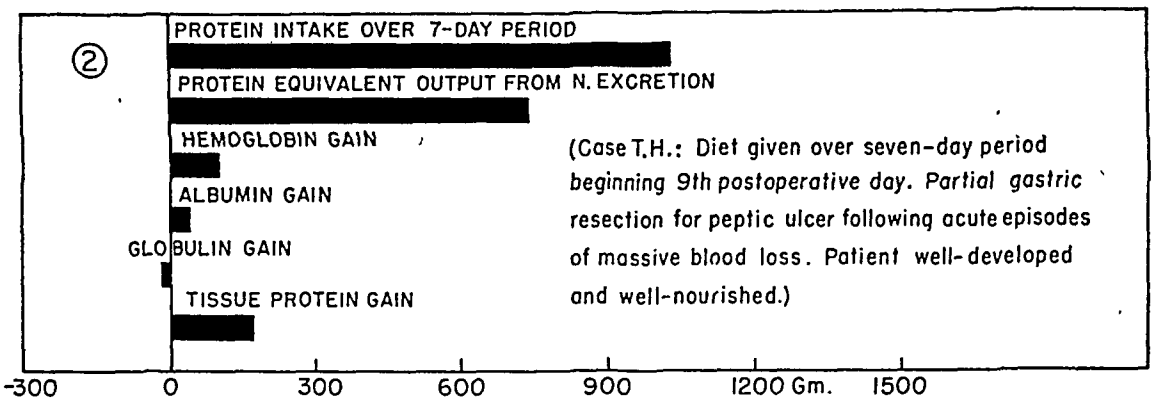



CHART 2.—Case T. H.: Nitrogen Balance Chart.

The diet was given over a seven-day period beginning on the 9th postoperative day. Operation was partial gastric resection for peptic ulcer following acute episodes of massive blood loss. The patient was well-developed and well-nourished.

CHART 3

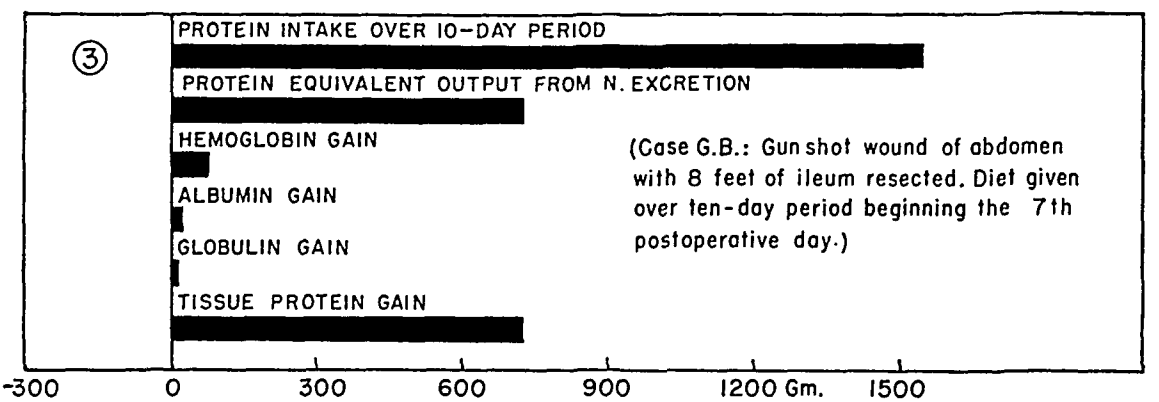



CHART 3.—Case G. B.: Nitrogen Balance Chart.

The injury was a gunshot wound of the abdomen. At operation eight feet of ileum was resected. The diet was given over a ten-day period starting on the 7th postoperative day.

Physical examination revealed a well-developed and well-nourished, lanky, colored male. Abdominal examination elicited no pathologic findings. The impression on admission was bleeding peptic ulcer with severe hemorrhagic anemia. The patient was transferred from medicine to surgery service February 12, and following a gastric irrigation, a modified Billroth-I anastomosis was performed under general anesthesia. Resection of the ulcer-bearing area was carried out. A Wangensteen tube was left in place postoperatively until February 15.

Laboratory findings were as follows: On admission the Hb. 20 per cent; W. B. C.

19,950, polys. 84 per cent. Urinanalysis revealed 5 W. B. C./H. P. F.; otherwise it was with normal limits. On February 12, the Hb. was 52 per cent. A Sippy diet regimen was carried out until February 21, at which time a special experimental diet was given for one week. Results are tabulated in Table I. The patient left the hospital seven days after completion of the dietary regimen in a much improved condition.

**Case** G. B. (Chart 3). This 16-year-old colored male was admitted to St. Philip Hospital emergency room, March 14, 1944, with a chief complaint of gunshot (.22-caliber) wound of the abdomen. The shooting occurred three hours prior to admission. He stated that vomiting occurred during this interval. No blood was present in the vomitus. Only slight external hemorrhage from the wound was evident. Physical examination revealed a well-developed and well-nourished colored male lying in bed in moderate pain. The patient was slow to respond to questioning. Generalized abdominal tenderness without apparent localization was present. Involuntary spasm was elicited. Slight dullness was found in both flanks with a tympanitic sound in the upper quadrants. Some distention was found and peristaltic sounds were audible. A small wound of entrance was present lateral to and 5 cm. above the anterior iliac spine. No wound of exit could be found. The patient was immediately prepared for operation. Under ether-oxygen anesthesia, a left rectus incision was made. After the peritoneum was opened, the abdominal cavity was found to be filled with a large amount of fresh blood. There were multiple perforations of the ilium and a few perforations of the jejunum. Part of the mesentery was badly punctured causing the corresponding ileum to have a dusky appearance. The smaller openings in the intestine were repaired with chromic catgut No. 0000 and reinforced with No. c silk. The bleeders in the mesentery were controlled. Eight feet of the ileum had to be resected because of injury to the corresponding mesentery. An open end-to-end anastomosis was done by a continuous running stitch of chromic catgut No. 0000. A Connell suture was taken in another location. The latter was reinforced by Cushing sutures. The mesentery was approximated with chromic catgut No. 0. The abdominal cavity was then irrigated with warm saline. Six grams of mixed sulfonamide powder was placed into the abdominal cavity. The abdomen was then closed. The patient's condition was good at the conclusion of the operation.

Laboratory studies revealed the following: On the day of admission Hb. 80 per cent before operation. On the second postoperative day the Hb. 63 per cent; W. B. C. 6,400, polys. 67 per cent. The urinanalysis was essentially negative. It is noted that the patient's icteric index on March 15 was 55 units and jaundice was noticeable. On March 20, the icteric index had dropped to 23 units. Six days following the operation the patient was placed on an experimental dietary regimen which was continued for ten days. Nitrogen balance studies were carried out during this interval and the results tabulated. The patient received 1,250 cc. of whole blood between admission and the second postoperative day. The patient's hospital course was satisfactory and he was discharged April 3, 1944, 20 days following admission.

**Case** J. H. (Chart 4) : This 58-year-old colored female was referred to the hospital emergency service, April 11, 1944, because of a large, left inguinal hernia which was incarcerated. History of her present illness dates back to ten years ago, at which time the patient noticed a small, intermittent swelling in the left groin. This swelling became progressively larger but remained reducible. During the past two years the hernia had occasionally become irreducible for varying periods. Nausea and vomiting were frequently associated with these periods of irreducibility. On the morning of admission the patient suffered a sudden attack of lower abdominal pain following a tremendous swelling of the left inguinal region. The patient became very nauseated and vomiting occurred. Her physician referred the patient to St. Philip Hospital for treatment.

Physical examination revealed a well-developed, well-nourished obese female lying in bed in a semiconscious, restless state and apparently in moderate shock. Abdominal examination revealed slight rigidity with few audible peristaltic sounds. No masses were

palpated except a very large, pendulous swelling in the left inguinal region. This mass was not reducible by continuous pressure. The patient was taken to the operating room and, under local infiltrative anesthesia, release of the incarcerated bowel with excision of the false skin sac followed by repair was done. The patient was returned to her room in fair postoperative condition.

Laboratory studies showed the following: On the day of admission, the Hb. 96 per cent; W. B. C. 17,850, polys. 90 per cent. Urinanalysis revealed a trace of albumin with

CHART 4

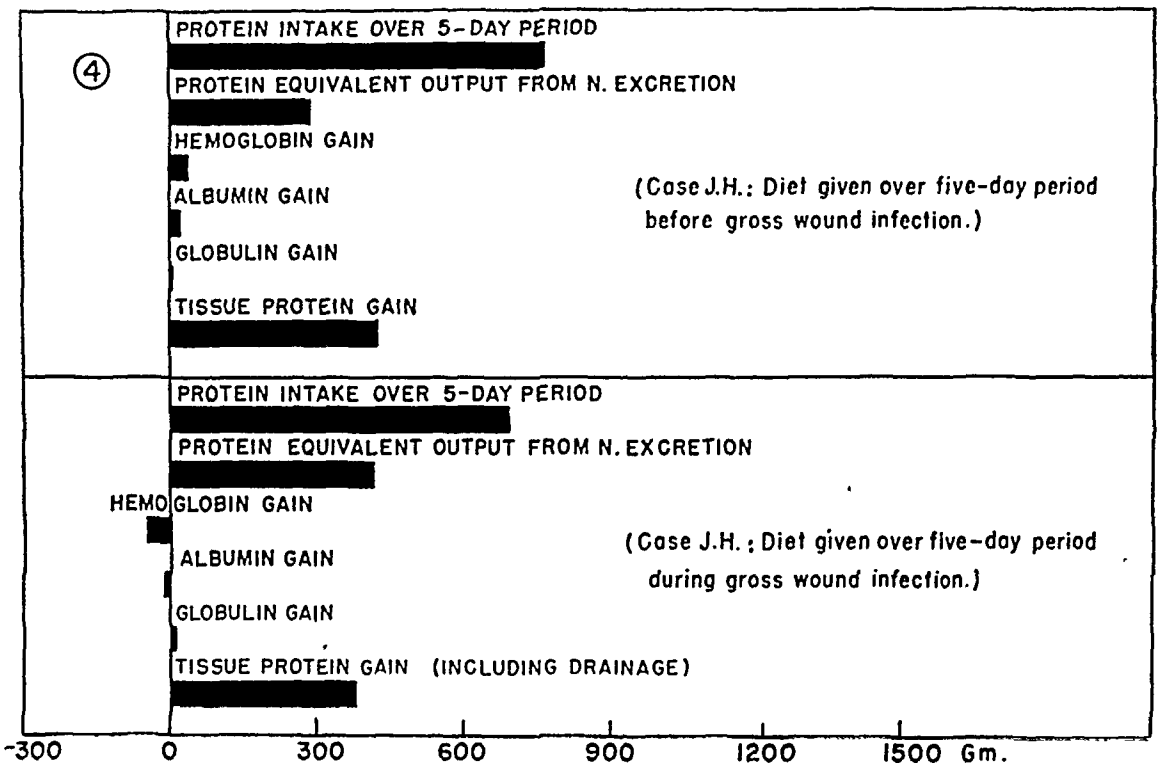



CHART 4.—Case J. H.: Nitrogen Balance Chart.
The diet was given for a five-day period preceding and during gross wound infection.

many granular casts, other determinations were within the normal range. On April 12, postoperatively the Hb. 71 per cent; W. B. C. 5,900; polys. 65 per cent. On May 2, the Hb. 62 per cent; W. B. C. 16,650, polys. 79 per cent. Subsequent urine examinations during the above period revealed no pathologic findings.

Following the operation, the patient had a low grade fever varying between 99° and 102° F. until April 21. Temperature at this time fell to within the normal range and only on three occasions reached 100° F. On May 1, 18 days postoperatively, her temperature spiked to 103° F. and continued to follow a septic course. Drainage from the local wound infection became more marked with the elevated temperature and systemic manifestations of gross wound infection were evident. An experimental dietary regimen was initiated April 26 and was continued until May 6. This included a five-day period when the wound infection was well localized and another five-day period when gross infection with spread and systemic reaction was present. Nitrogen balance and blood regeneration studies were followed and tabulated. Patient was finally discharged June 21, 1944, following healing.

**Case** M. P. (Chart 5): This 18-year-old white female was admitted to Gynecologic Service, June 14, 1944, with a chief complaint of vaginal bleeding of 21 days duration. The bleeding began as a normal period but increased in amount and persisted.

Physical examination revealed a pale, malnourished, asthenic patient. The spleen was palpable and hard. The veins of the fundus were quite tortuous. The uterus was somewhat enlarged and boggy with probable prolapse of the left ovary. Laboratory studies showed the HB. 30 per cent; W. B. C. 7,000; and urinanalysis revealed 8 W. B. C./H. P. F. The patient was treated with mocassin venom, iron, and two transfusions. Vaginal bleeding ceased. On June 22 the patient's temperature rose to 104° F. and sulfadiazine medication was given. Because of the continued fever, enlarged spleen, and anemia, the patient was transferred to the Medical Service. Blood studies disclosed nothing except an increased bleeding time of 23 minutes. Roentgenograms of the chest, routine agglutinations and blood cultures were repeatedly negative. The patient was placed upon an experimental dietary regimen July 7, and maintained for one week. Nitrogen balance and blood regeneration studies were carried out during this interval and tabulated. One week following completion of the experimental study the patient began to bleed again. She was proved to be *Rh*-negative, and difficulty was encountered in finding subsequent blood for transfusion. The patient was given a short course of radium therapy to stop the bleeding and was finally discharged in good condition.

COMMENT.—Nitrogen retention was good in all cases, averaging in some subjects over one-third of the nitrogen intake. It was interesting to note that where malnourishment and anemia were prominent factors as shown by the

CHART 5

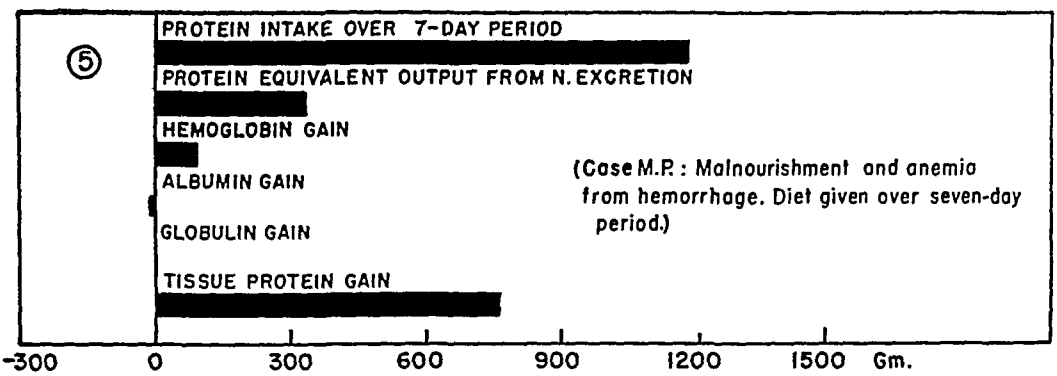



CHART 5.—Case M. P.: Nitrogen Balance Chart.

Patient was suffering from malnourishment and secondary anemia that resulted from hemorrhage. The diet was given over a seven-day period.

Cases of C. T. (Chart 6) and M. P. (Chart 5), hemoglobin, plasma protein, and tissue protein formation closely paralleled the results of Robscheitt-Robbins[12] with hypoproteinemic dogs. That is, for every Gm. of plasma protein formed, two to four Gm. of hemoglobin and 10 to 30 Gm. of tissue protein were formed. Cases which appeared to be well-nourished, however, but in whom blood loss was a prominent factor used a greater percentage of the retained nitrogen for plasma protein and hemoglobin formation. This point is brought out by comparing the case of partial gastric resection which suffered acute episodes of bleeding just prior to operation (Case T. H.) with that of chronic depletion of body protein due to continued bleeding (Case M. P.) or continued wound drainage (Case C. T.). Both of these latter cases were asso-

ciated with inadequate food intake over a month's period of time before experimental diet was initiated.

Blood regeneration in cases where acute infection was present revealed suppression of hemoglobin formation even to the extent of hemoglobin loss. This occurred in spite of the fact that nitrogen retention was quite satisfactory.

CHART 6

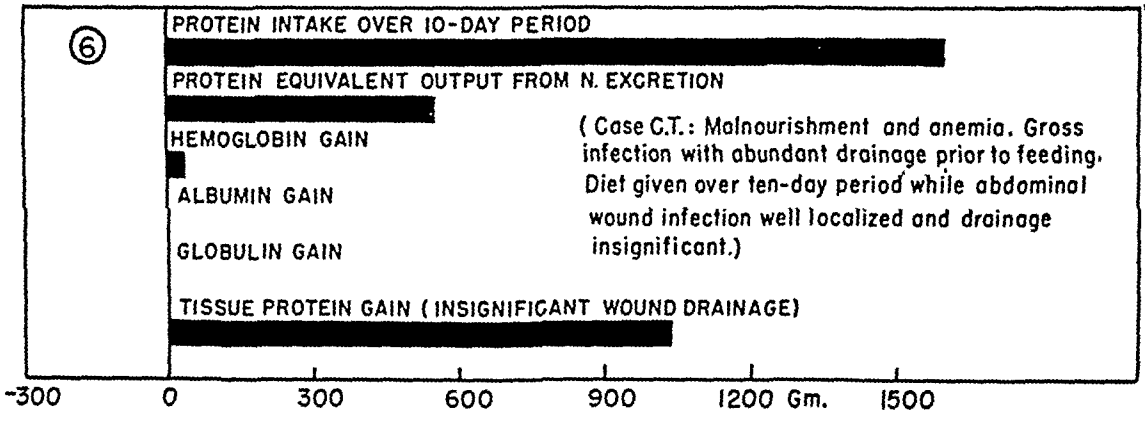



CHART 6.—Case C. T.: Nitrogen Balance Chart.

The patient suffered from malnourishment and anemia. There was gross wound infection with abundant drainage prior to feeding. The diet was given over a ten-day period when abdomen wound infection was well localized and drainage not significant. Nitrogen balance studies were made during this period.

CHART 7

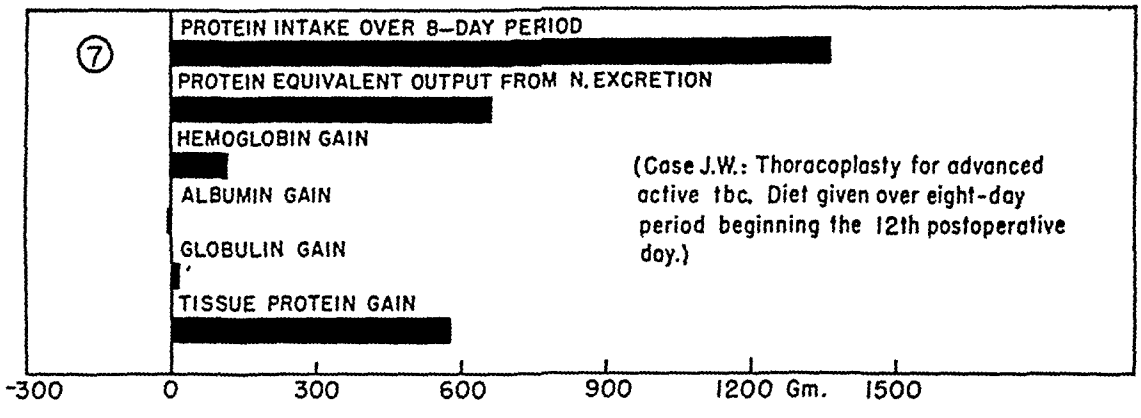



CHART 7.—Case J. W.: Nitrogen Balance Chart.

The patient suffered from advanced active tuberculosis for which a thoracoplasty was performed. The diet was given over an eight-day period starting on the 12th postoperative day.

Plasma albumin and globulin regeneration was variable although it also tended to be suppressed. Some cases, however, manifested accelerated plasma globulin formation in the presence of infection. This is illustrated by the studies of Case J. H. (Chart 4) and Case J. W. (Chart 7) as shown in the accompanying charts and Table I. The first patient was followed five days before gross wound infection occurred, and five days during infection. In the absence of infection, blood regeneration was similar to that manifested by the other uncomplicated cases. During infection, hemoglobin and plasma albumin loss occurred,

whereas the total circulating plasma globulin increased. Another Case, that of B. A. (Chart 8), presented gross infection from the beginning, and during a seven-day study period lost one-third of her total circulating hemoglobin. Both plasma albumin and globulin revealed increases and nitrogen retention was excellent. This patient was quite edematous at the start of the feeding period. Her plasma protein concentration at this time was 5.96 Gm. per 100 cc. plasma, with a plasma volume of 3,569 cc.; at the end of a seven-day period,

CHART 8

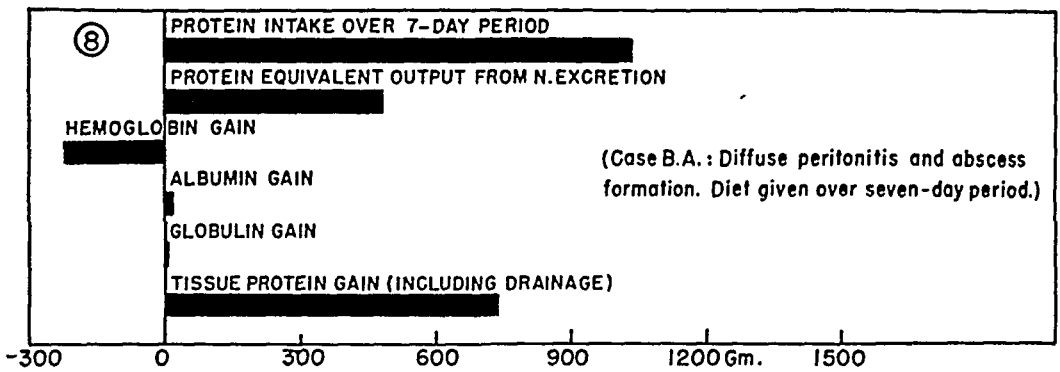



CHART 8.—Case B. A.: Nitrogen Balance Chart.

Diffuse peritonitis with abscess formation. The diet was given over a seven-day period.

most of the clinical edema had disappeared and her plasma protein concentration was 6.97 Gm. per 100 cc. plasma, with a plasma volume of 3,292 cc. Probably the greatest factor in the loss of edema was the low sodium chloride regimen rather than actual gain of plasma protein which was in reality quite small.

Our results in relation to plasma protein concentration and plasma volume are in accord with those of Lyons, Madden and Whipple, and others.[13-16] Very little correlation could be established between plasma protein concentrations and plasma volume, and, in turn, total circulating plasma protein. Both values tended to show the same directional shift but much variation is apparent. Unpublished data of Evans and Forbes[17] tends to further emphasize these findings.

## SUMMARY

It is believed that a high protein, high caloric, high vitamin diet in liquid form is feasible to administer to selected postoperative patients. The type of diet in this study has been well utilized and probably could be employed to advantage in some cases where more expensive modes of nitrogen intake are contemplated.

A method has been presented which facilitates nitrogen balance studies by the use of a uniform, liquid diet whose protein intake is easily determined.

Positive nitrogen balance was established in all patients studied. Protein regeneration tended to be more marked in those tissues where competition was greatest for the available amino acids.

In the presence of infection, hemoglobin regeneration did not equal its destruction. Plasma albumin and globulin formation were variable.

Plasma protein concentration and hemoglobin determinations *per se* do not reflect plasma protein and hemoglobin regeneration.

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# BRIEF COMMUNICATIONS

## GASTROJEJUNOCOLIC FISTULA FOLLOWING GASTRECTOMY

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THIS DISCUSSION was prompted by the recent consideration of a patient, who had a gastrojejunocolic fistula, following gastrectomy. The patient was in very poor condition, and had a concomitant acute intestinal obstruction, which made necessary some sort of modified procedure in regard to the fistula. In the past it has been our practice to resect the involved portion of the jejunum, large bowel and stomach, repair the bowel and jejunum, and reform the gastrojejunal anastomosis.

We were familiar with the side-tracking, two-stage procedure, of Lahey and Marshall, and of Pfeiffer and Kent's stage procedure, using a proximal colostomy as the first stage. With the number of previous celiotomies had by this patient, a stage procedure was difficult to contemplate. Therefore, the following plan was visualized, and turned out to be practicable:

The adhesive band causing the intestinal obstruction was first freed. The colon was disconnected from the gastrojejunal anastomosis and its opening closed by two layers of catgut sutures overlayed by one layer of interrupted figure-of-8 cotton No. 40 sutures. The ulcer and gastrojejunal anastomosis was thus opened in part, and no more than necessary. The edges of the fistulous tract were excised and the anastomosis repaired, having interfered with less than one-third of the circumference of the anastomosis in the dissection. The time elapsed was short and the trauma slight. An uneventful convalescence supervened, and rapid weight-gain occurred.

**Case Report.**—Case No. 8598: E. C., a 32-year-old, white male, entered St. Vincent's Hospital, September 13, 1945, with the complaint of vomiting and abdominal pain. For the last nine months, the patient has had attacks of abdominal pain with periodic attacks of vomiting of foul liquid, gray-colored material, and of bowel movements of the same character.

In 1935, the patient had a perforation of a peptic ulcer, without previous history or warning. The perforation was closed at that time.

In 1937, the patient had an acute mechanical intestinal obstruction, caused by adhesions; and six feet of terminal ileum had to be resected, because of strangulation.

In 1942, the patient again had a perforation without any previous symptoms; and after closure of the ulcer had persistent ulcer symptoms. Several months later, he had a subtotal gastrectomy, posterior Hoffmeister-Finsterer type. The patient was quite well then, until in March, 1945, at which time he began to have abdominal pain, gray-colored vomitus and stool; and on upper gastro-intestinal roentgenologic examination and gallbladder dye test, gallstones were found, and no gastrojejunocolic fistula demonstrated. The gallbladder and stones were removed, in May, 1945, and following this, the patient developed two mechanical intestinal obstructions, both of which were operated upon and, in the second instance, a Miller-Abbott tube was threaded clear down to the colon. This was left in place for 12 days. The patient gained some weight but still continued to have periodic attacks of some type of vomiting and, on re-



FIG. 1.—Roentgenogram of the gastrojejunocolic fistula. Barium from stomach immediately entered the colon as well as the jejunum.



FIG. 2.—Roentgenogram showing superimposed acute intestinal obstruction while patient was awaiting surgery for the fistula.

# ACUTE INTESTINAL OBSTRUCTION CAUSED BY CLAMPING OF THE INTESTINE IN THE UMBILICAL CORD CLAMP

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The case, that we are presenting, is that of a newborn infant, who had an accidental Mikulicz' procedure performed upon the small bowel by the placing of the umbilical cord clamp. The case is reported because of its great rarity, and as a reminder to all that such an accident may take place. In tying or clamping the cord, especially one that is unduly large, it should be tied well away from the abdomen.

**Case Report.**—Nos. 147752 and 95862; Doernbecher Hospital: The child, a four-day-old white female, entered Doernbecher Hospital, September 7, 1945. It was a full term, spontaneous delivery, birth weight 7 lbs. 13¾ oz. The child was admitted vomiting, with the history of bleeding and intestinal contents coming from the umbilical cord. The child was born with a very large cord, approximately 1.5 inches in diameter and the cord clamp was used. The day before admission, September 6, 1945, the child began to vomit. This consisted of a green bile-stained material. The morning of admission some bleeding was noted from the umbilicus, so the clamp was placed closer to the abdomen. At 4:30 P. M. more bleeding occurred, and this was attempted to be controlled by the local physician. At that time bowel content was seen to come from the wound.

When the child was admitted to Doernbecher Hospital it was extremely ill, with a temperature of 104.6 F., pulse 160, respiration 32. Physical examination revealed an apical systolic murmur in the heart; a distended abdomen, and an incision across the umbilicus which had been sutured, a small stump protruding below the incision. The plain film of the abdomen showed some distension of the small bowel (Fig. 1); and a roentgenogram of the chest showed the heart on the right side of the body.

Because of the history and physical findings, the child was taken to the surgery immediately, and it was found, after dissection of the sutured stump, that a loop of small bowel had been caught in the cord and the blind ends were necrotic and were leaking bowel content. The proximal loop of small intestine was very dilated, the distal end was collapsed, being about the thickness of a cigarette. The stumps were closed in three layers and a side-to-side anastomosis was performed (Fig. 2). The primary closure of the abdomen was then done.

The postoperative course was exceedingly stormy. Considerable distension of the abdomen was present, with vomiting and fever. The child was given blood transfusions, oxygen, penicillin and continuous gastric suction. About the 8th postoperative day suction was able to be discontinued, and the child continued to progress favorably until discharge on October 10, 1945. Further studies of the heart revealed a congenital lesion, in addition to the malrotation of the heart. At discharge, October 10, 1945, the child was eating very well, having normal bowel movements and having no difficulty as far as the abdominal wound or the heart were concerned.

This case may be considered to fall into the rather rare condition of hernia into the umbilical cord, or omphalocele, as it is perhaps better termed, in order to separate it from the ordinary types of umbilical hernia.

From the sixth to the tenth week in the embryo, the base of the umbilical cord contains loops of intestines. After the tenth week, the intestines nor-




FIG. 1.—Roentgenogram showing dilated small bowel following the accidental injury of the bowel by the umbilical cord clamp.

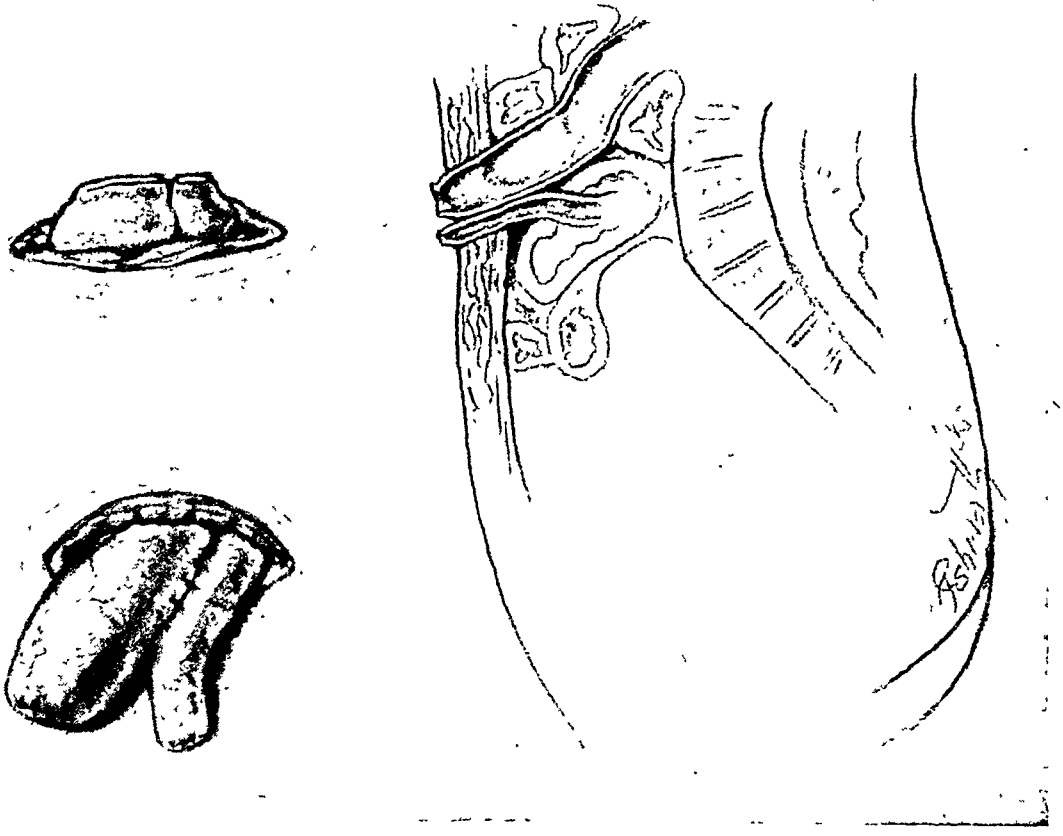


FIG. 2.—(Upper left) : The appearance of the bowel after it had been injured.
(Right) : Sagital section showing same.
(Lower left) : Beginning of the lateral anastomosis after closure of both ends of the divided bowel.

mally recede into the abdomen; if they do not, an omphalocele results. Such umbilical eventrations may be very small or quite large. In such cases, the abdominal viscera are covered by a very thin covering, which rapidly dries and becomes necrotic. Thus, repair of such defects must be undertaken in the first few hours of life. This, of course, differs from the surgical treatment of the ordinary umbilical hernia, which is not operated upon prior to the age of one year, unless the defect is very great or unless evidence of incarceration is noted. The ordinary umbilical hernia is caused by a weakness of the rectus fascia with diastasis of the recti muscles, and, of course, is covered by skin and not by the thin parchment-like membrane of the cord.

SUMMARY

(1) The successful outcome following the lateral anastomosis of the injured small bowel is ascribed to the diligent care of a very capable House staff of doctors and nurses, whose ability to give a newborn infant daily transfusions and intravenous solutions over the critical period spelled the difference between life and death.

(2) The probable reason that this bowel was injured is that a small congenital hernia into the umbilical cord, or omphalocele, was present.

(3) All cords, especially unusual looking ones, should be clamped well away from the body.

(4) Herniae into the umbilical cord, or omphalocele, should be repaired immediately after birth.

# A TRANSFASCIAL INCISION AS AN APPROACH TO THE KIDNEY AND RETROPERITONEAL SPACE

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A PROPER INCISION is one that adheres to physiologico-anatomic principles and procures a good operative field with the least amount of tissue damage and time wasted. Although no claim of originality is made for the above incision, I have not seen it described in the literature.

All incisions used as an approach to retroperitoneal surgery, including the 12th-rib incision, recently described by Digby, of China, and better known as the "Clairmont method," tend to sever important tissues and are too close to pleura and peritoneum, to be trouble-free for the general surgeon.

During the last seven years, I have employed the transfascial incision in operations upon the sympathetic and urinary systems, and because of its simplicity and safety, feel it worth while reporting. The incision is wholly through fascial tissue, without muscle-cutting or -splitting, roomy, free from danger of entering pleura or peritoneum, easy of closure, and without danger of herniation. It is also shockless and time-saving. A brief anatomic description and technic follows:

*Anatomy.*—The lumbodorsal fascia (Fig. 1) is in two layers, anterior and posterior, forming a sheath for the sacrospinalis muscle. The anterior layer, in turn, unites with the aponeurosis on the quadratus lumborum muscle to form a sheath for the latter muscle, both sheaths fusing lateral to these muscles to form a common tendon, or origin for the transversus abdominis muscle.

The transversalis fascia, which is scanty in this region, unites with the subperitoneal fascia and the aponeurosis of the quadratus lumborum and psoas to form the prerenal fascia which, in turn, encloses the kidney and its fatty capsule. Behind the renal fascia there is considerable fat, constituting the paranephric body.

The subcostal, ilio-inguinal, and hypogastric nerves transverse between quadratus lumborum and its fascia to their respective distribution.

The lumbar vessels arising from the aorta, cross behind the quadratus lumborum muscle to enter the space between the transversus abdominis and obliquus internus to their respective distribution.

The kidneys, suspended through the renal fascia and apposition of neighboring viscera, lie with their upper poles on a level with the upper border of the 12th thoracic vertebra, the lower poles on a level with the 3rd lumbar vertebra; the posterior surfaces being largely on the quadratus lumborum muscles.

The order of structure, therefore, from skin surface to kidney (Fig. 1), are skin, superficial fascia, posterior layer of lumbodorsal fascia, sacrospinalis muscle, anterior layer of lumbodorsal fascia, lumbar vessels and nerves, (sub-

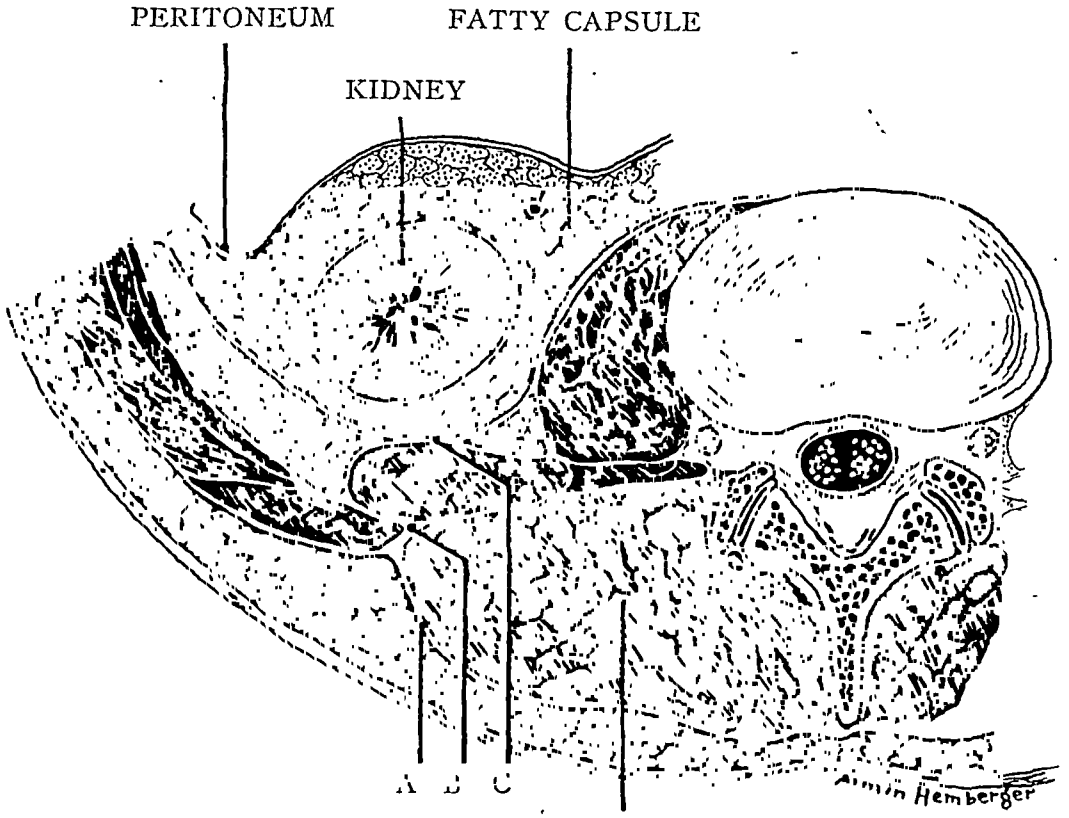



FIG. 1.—Showing structure of the lumbodorsal fascia.

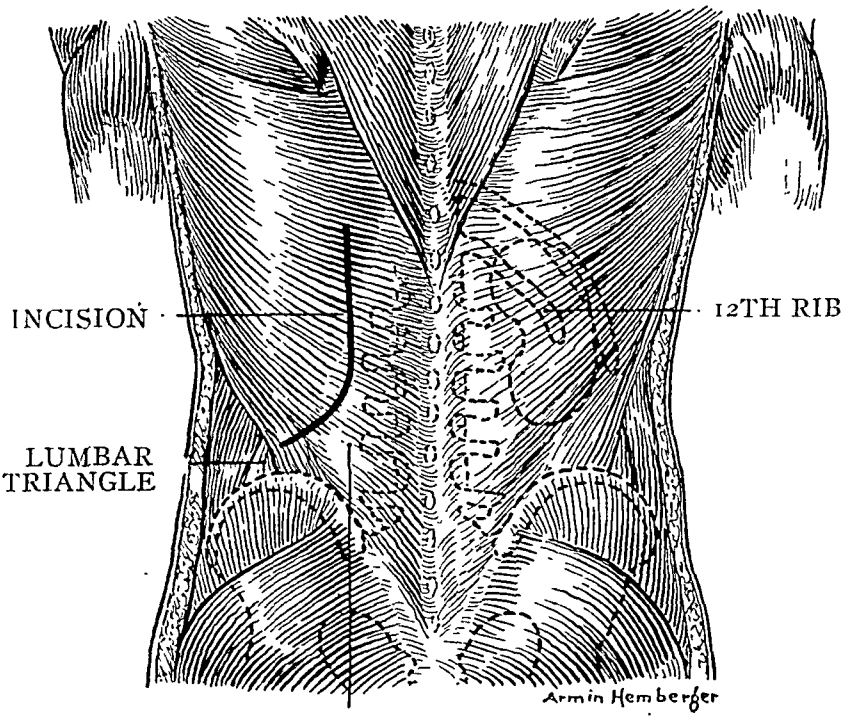



FIG. 2.—Illustrating operative technic.

costal, ilio-inguinal, and hypogastric), transversalis fascia, (fusion of transversalis subperitoneal and aponeurosis of quadratus lumborum) and kidney.

*Technic.*—General, spinal-paravertebral or local anesthesia may be employed. The usual kidney position, with moderate Fowler's, is most satisfactory. A vertical incision with a lower horizontal limb is used, extending from the 12th rib to crest of ileum at outer edge of sacrospinalis muscle and parallel with the vertebral column (Fig. 2). If more room is required, the 12th rib may be cut transversally and subperiostially, or the horizontal limb may be prolonged, without danger of injuring pleura or peritoneum. These prolongations are rarely necessary, having been used on one occasion only, due to a marked scoliosis present.

Incise skin, superficial fascia, and posterior sheath of sacrospinalis; retract the latter muscle and incise anterior sheath to quadratus lumborum, retract this muscle, and incise its anterior sheath, which forms a part of the transversalis fascia with the subperitoneal fascia, and the kidney with its fatty capsule, presents itself anterior to operative field (Fig. 1 a, b, c).

Minor vessels and nerves can be ignored, avoiding the subcostals, ilio-inguinal, hypogastric and the deep iliac circumflex from above downward, respectively.

There is no muscle-cutting or -splitting, no danger of entering peritoneum or pleura nor injuring any important structures, and postoperative hernia has never occurred. All the retroperitoneal tissues are within the surgeon's reach and can be dealt with, without difficulty. Better control of the pedicle, pelvis, and ureter can be had with this incision than any other used at present. The time-element is greatly reduced, and the incision is simple of performance and closure. Palpation of the opposite kidney has been possible in obscure cases.

The writer has used the described incision, obtaining free exposure and success for the removal of large kidneys, such as hypernephromas, sarcomas, hydropyonephrosis, and kidney and ureter stones. The same incision has also been used by the writer for operations upon the sympathetic system, such as splanchnicectomy, celiac ganglionectomy, lumbar ganglio- and ramisectomy.

SUMMARY

A simple incision is described which fulfils all the physiologico-anatomic principles.

The illustrations are taken from Gray's Anatomy.

# GANGLION OF THE COMMON PERONEAL NERVE

CASE REPORT

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GANGLION in the neighborhood of the knee joint is not uncommon. There are few surgeons who have not resected a cystic structure adherent to the muscles, tendon, or ligaments around the knee and have found that it is difficult to remove without spilling its clear, jelly-like contents and leaving behind some of its poorly defined posterior wall. Ganglion of a peripheral nerve, however, is so rare[1] that it appears fitting to record a recently encountered case in which the common peroneal nerve was involved and had to be resected.

Insofar as can be determined there are five previously recorded cases of ganglion of a peripheral nerve. In 1901, Hartwell[2] recorded a case in which the median nerve was involved. Loeffler and Volkmann,[3] in 1920, reported a ganglion of the tibial nerve, 1 x 2 cm. in size, which produced pain and paresthesia, causing a mistaken diagnosis of foot strain in a 36-year-old railroad worker. In 1922, Sultan[4] recorded a ganglion, 2 x 3 cm., causing pain and complete paralysis of the deep peroneal nerve in a 56-year-old male. The pain, but not the paralysis, was relieved by dissection of the ganglion from the nerve. Dubs,[5] in 1922, found a small ganglion of the dorsal branch of the ulnar nerve in a 68-year-old man. In 1937, Ferguson[6] reported a case in a 15-year-old boy, in whom the ganglion, 6 x 3 cm. in size, arose from the sheath of the peroneal nerve and, fortunately, could be dissected from it.

**Case Report.**—A 29-year-old male, sports director in the American Red Cross, entered the hospital complaining of the appearance, six weeks previously, of a lump below and lateral to the left knee followed, three weeks later, by a numbness of the lower leg and a drop foot. There had been no antecedent trauma or other precipitating factor.

Examination showed a rubbery, spindle-shaped mass lying over the head of the left fibula following the course of the common and deep peroneal nerves. There was no tenderness. There was complete paralysis of the common peroneal nerve with drop foot, reaction of degeneration in the anterior tibial and peroneal muscle group, and a typical loss of sensation in the distribution of the common peroneal nerve.

Operation, three days after admission, performed under gas-oxygen-ether anesthesia, revealed a multilocular mass, 6.5 × 3.5 × 3.0 cm., containing clear jelly-like material characteristic of a ganglion. Incorporated in the wall of the ganglion, over a band 2 cm. in width, ran the common peroneal nerve. Small locules of cyst were lying at many points among the nerve fibers which seemed edematous and abnormal. In view of the already complete paralysis, the total involvement of the nerve by the cyst, and the appearance of the fibers, a complete resection of the ganglion and involved nerve was performed. At the lowermost end of the ganglion a small pedicle of the cyst left the nerve trunk and was attached to the tibiofibular ligament just below the knee joint.

The patient's postoperative course was uneventful. He was able to walk about normally, with an appliance to correct the drop foot. He was referred to another hospital for the consideration of the possibility of a nerve graft. Because of retraction of nerve ends the gap in the nerve amounted to about 7 cm., and little hope was held out for success of this procedure.

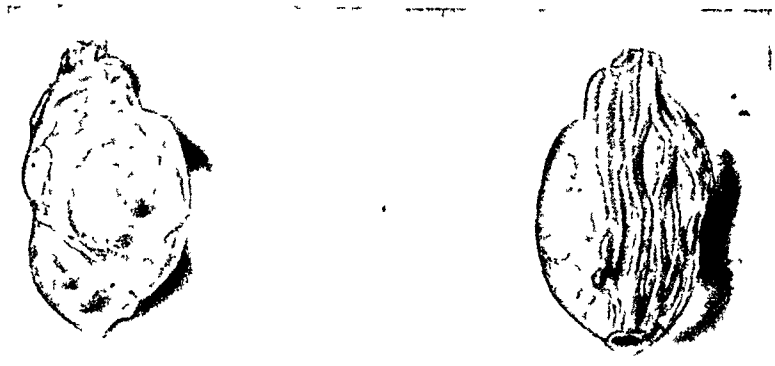


FIG. 1.—Gross appearance of the ganglion. It is here depicted as slightly less than half its actual size (6.5 × 3.5 × 3.0 cm.).



FIG. 2.—Low power photomicrograph of the wall of the ganglion.

*Pathologic Examination.*—"The specimen shows the wall of a cystic structure formed of connective tissue, without specific lining cells. The lining and wall are formed of collagenous connective tissue. There are patches of loosely arranged myxomatous tissue. Nerves course both through and over the cyst wall, and myxomatous zones are present in epineurium and perineurium. The smaller cystic structure is

formed of collagenous connective tissue including a cyst similar to the above which contains granular coagulum. Two nerve fasciculi are present in the immediately adjoining tissue. One luminated structure is partly lined by fibrous synovial membrane."

DISCUSSION.—From the descriptions of the cases of Hartwell, Loeffler and Volkmann, Sultan and Dubs, and the detailed description of Ferguson's case, the patient, here recorded, appears similar to them in all respects but one. In none of the other cases had the involved nerve to be resected. In only one case, however, that of Sultan, had the nerve function been totally destroyed by the ganglion. He produced no clinical improvement by excision. In the other four cases in which the clinical signs were those of partial nerve involvement, immediate improvement or disappearance of the neurologic signs resulted.

In none of the reports is recurrence mentioned, but those cases, just as this one, were not followed for long enough, so that conclusion can not be drawn on this point. The great tendency for ganglia arising in or from the bursae, ligaments or tendons about the knee joint to recur is mentioned often in the literature and has been observed in the clinical experience of the writer. A recurrence as late as 18 years after the original excision has been recently seen.

The etiology and pathologic characteristics of ganglion have been the subject of much speculation. The papers of Ledderhose,[7] Floderus,[8] Carp and Stout,[9] King,[10] Jensen,[12] and Ferguson[6] present the various theories as to etiology that have been offered. There is a general consensus that these ganglia about the knee joint, which are multilocular, contain mucinous jelly-like material and do not communicate with the joint, are entirely different from the synovial cysts (Baker's cysts) which contain clear fluid and usually communicate with the knee joint. The latter may be herniations of synovia but are more probably distentions of the gastrocnemio-semimembranosus bursa (Wilson, Eyre-Brook and Francis[13]). The former, with which we are here concerned, are the product of a reaction, degeneration or metaplasia of the connective tissue around a joint. Ledderhose, Carp and Stout, and Ferguson believe that they are the result of a mucinous degeneration of connective tissue. King holds to the theory that the spindle cells of the connective tissue around a joint respond to the stimulus of trauma or friction, undergo metaplasia, secret mucin and, thus, form pseudojoint cavities—which is what ganglia really are. Jensen brings up the possibility of embryonic rests of ectopic synovial tissue. Wherever the truth of the matter lies, it seems clear from their nature and proximity to joints that they bear some definite relationship, whether by descent or by imitation, to the synovial tissue.

The question as to whether the ganglia which involve peripheral nerves arise in the connective tissue of the epi- or perineurium or whether they arise in neighboring structures and invade the nerve is also to be settled. Carp and Stout believe the latter to be the case. In the case recorded there was a stalk or pedicle leading from the tibiofibular ligament, suggesting that mechanism here. We must conclude that any of the connective tissue elements around a joint, including the perineurium, may be the origin of ganglion which occurs as the result of some unknown stimulus.

SUMMARY

1. A case of ganglion of a peripheral nerve is reported.

2. A review of the literature with a summary of the theories as to the etiology of the condition is presented.

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# STUDIES ON THE INGUINAL REGION
# II. THE ANATOMY OF THE INGUINAL (HESSELBACH) TRIANGLE

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ALTHOUGH the inguinal (Hesselbach) triangle is the location of some five per cent of all herniae encountered, nevertheless, a protrusion here can be as disabling as one in any location. It would seem that an area so frequently dissected in the laboratory and observed so often by surgeons would be thoroughly understood and agreed upon by all workers. There is disagreement as to the precise location of a direct (diverticular) hernia as well as its relation to the ventral abdominal wall. Two types of hernia occur in the inguinal triangle. The most important one is the diverticular variety which closely simulates the direct form except in point of origin and relation to the spermatic cord. The second form is a general bulging of the whole triangle and sometimes of the whole lower abdominal wall. Andrews[1] (1934) refers to this type as the despair of the surgeon. This type has not been encountered and will not be considered in this study.

Our objective has been to correlate the fundamental anatomy of the inguinal triangle and to indicate the relationships of a direct (diverticular) hernia to the layering of the ventral abdominal wall.

## MATERIALS AND METHODS

During the past ten years a record has been made of 12 direct (diverticular) herniae encountered in the gross anatomy laboratory at West Virginia and the University of Pittsburgh Medical Schools. These observations have been supplemented by a study of the parietal layers of the ventral abdominal wall in specimens where no hernia existed. A total of 268 body-halves have been considered. All direct herniae were in males except one. This form of hernia is extremely rare in the female. The one encountered did not differ from those present in males.

1. *The Peritoneum.*—There are at least three structures that may produce prominent folds of the peritoneum. These are the urachus, the obliterated hypogastric arteries and the deep inferior epigastric arteries. In some specimens the folds are very shallow and in others quite deep. Plicae as tall as 4.1 cm. have been observed. They are more frequently associated with the obliterated umbilical arteries than with the urachus or the deep inferior epigastric arteries. They are sometimes bilateral but may be present on one side only (Fig. 1).

2. *The Transversus Fascia.*—This name has been chosen in preference to the generally used term "transversalis fascia." The term transversus is appropriate, because it refers to a true deep fascia and because it is associated with the transversus muscle, Anson[2] (1938). Any muscle or aponeurosis has

an areolar tissue on each aspect. This areolar tissue does not represent a deep fascia, in the sense that this term is generally employed, Grant[5] (1944). If it were not for the loose areolar tissue surrounding structures they would not be able to glide over each other during movement. In the instance under consideration the transversus fascia is a direct continuation of the dorsal layer of the rectus sheath. When the peritoneum is carefully removed from the lower ventral abdominal wall, there is left the dorsal portion of the rectus sheath. This dorsal portion of the rectus sheath can be separated from the rectus muscle and below the level of the linea semicircularis continues as the true transversus fascia. It attaches along the line of origin of the transversus muscle but is directly continuous with the iliac fascia. This establishes it as a true deep fascia. The degree of development is in proportion to the muscular development of the individual. In sparse individuals it may be thin and close to the peritoneum, but in stout ones considerable preperitoneal tissue may intervene.




FIG. 1.—Photograph of the internal surface of a left half of the ventral abdominal wall, showing a fossa 4.1 cm. deep made by the obliterated hypogastric artery. (a) The peritoneal fossa; (b) obliterated hypogastric artery; (c) rectus abdominis muscle; (d) urinary bladder.

3. *The Conjoined Aponeurosis.*—The internal oblique and transversus muscles unite to make the conjoined aponeurosis. Careful consideration has been given to the medial and inferior extent of these two muscles and their aponeuroses. In general, the muscle portion of the internal oblique extends further medially than that of the tranversus. In the 268 body-halves examined the internal oblique was muscular in the whole of the inguinal triangle in 20% of all specimens, furnished no muscle in 31.7%, and in 48.3% the muscle portion made up one-half or more of the inguinal triangle. In the same specimens the transversus furnished no muscle tissue in the triangle in slightly over 54.6% of the body-halves, covered the whole inguinal triangle in less than 4.1% and made up one-half of the triangle in 41.3%.

The inferior extent of these muscles is also important. The internal oblique arises from the whole of the inguinal ligament down to the spermatic cord. Chandler and Schadewald[4] (1944), Anson (1938). In contrast the transversus arose from the whole of the inguinal ligament in 5% of the 268 body-halves. Anson (1938) reported an incidence of 3% in 200 body-halves. Even

when the transversus does not arise from the whole of the inguinal ligament it may be represented by a fascial or aponeurotic layer (Figs. 2 and 3).

4. *The Aponeurosis of the External Oblique.*—This layer most nearly fits the usual description found in most textbooks. The size of the internal abdominal ring varies considerably. When large the oblique fibers associated with the ring may also be separated somewhat. A reflected inguinal ligament —a portion extending upward and medially—was rarely observed. Thinned-

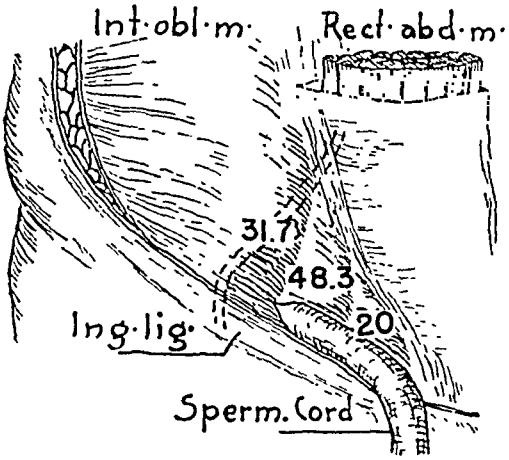



FIG. 2

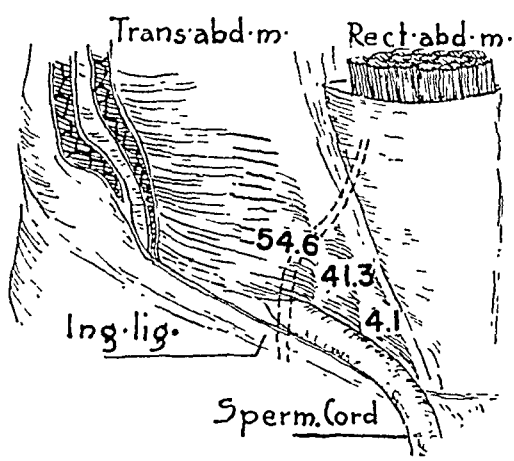



FIG. 3

FIG. 2.—The medial extent of the internal oblique as muscle into the inguinal (Hesselbach) triangle. In 20% of 268 body-halves this muscle extends through the whole of the triangle and in some instances overlapped the rectus. About one-half of the triangle was muscular in 48.3% and only slightly, or not at all, in 31.7%. Deep inferior epigastric artery is shown by dotted lines.

FIG. 3.—The medial extent of the transversus abdominis as muscle into the inguinal (Hesselbach) triangle. In 4.1% of 268 body-halves this muscle extended through the whole triangle, and occasionally overlapped the rectus. About one-half of the triangle was muscular in 41.3% and only slightly, or not at all, in 54.6%. Deep inferior epigastric artery is shown by dotted lines.

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out or fascial areas may be present occasionally. This layer does not unite with the rectus sheath until near the midline, as described and illustrated by Anson and McVay (1938).

DISCUSSION.—What are the elements of weakness which precede the formation of a direct hernia? The presence of fossae on either side of the obliterated hypogastric arteries are thought to concentrate intra-abdominal pressure in a restricted area. If the peritoneum is stretched over such a region a protrusion is gradually formed when the fossae extend inferior to the inguinal ligament the protrusion may be into the femoral canal.

These fossae in the peritoneal layer may permit the beginning of a protrusion but if it is to become extensive at all it must find weak areas in other layers also, especially the conjoined aponeurosis.

Direct herniae have been encountered in the absence of peritoneal fossae. Probably the most important single factor in the strength or weakness of the

ventral abdominal wall is the condition of the conjoined aponeurosis in the inguinal triangle. If either the internal oblique or the transversus are muscular in the triangle protrusions may take place since muscle fasciculi are often held together only slightly by fibrous tissue. Hernial protrusions have also been found in the aponeurotic portion of the triangle. By subjecting each layer of the ventral abdominal wall to a bright light thinned-out fascial areas are sometimes noted. It is assumed that these thinned-out regions are the ones where direct herniae occur. In one specimen bilateral herniae were present. On one side the protrusion was just superior to the inguinal ligament and in the supravesical fossa. The sac, about the size of a lead pencil, did not contain any viscus. The protrusion extended through the external inguinal ring and down the spermatic cord a short distance. On the opposite side the hernia arose in the medial inguinal fossa. Observers are about equally divided as to the most common fossa of origin; some report that direct hernia is almost always found in the supravesical fossa and about an equal number state that it usually arises in the medial inguinal fossa. Of the 12 direct herniae observed in this series seven were in the supravesical and five in the medial inguinal fossa. This number is far too small to be significant but it may indicate that protrusions are about as likely to occur in one as the other fossa. There is probably but little difference to the surgeon which fossa gives origin to the protrusion.

The aponeurosis of the external oblique is somewhat less important than fossae in the peritoneum or thinned-out areas in the conjoined aponeurosis. If weak areas or a dilated external ring exist, these contribute to the general weakness of the wall. Neither of these conditions predispose to a direct hernia. The primary fundamental weakness is the presence of peritoneal fossae and weak thinned-out areas in the conjoined aponeurosis. The result of a protrusion through the external inguinal ring is dilation of the ring and enlargement of the fascial coverings of the spermatic cord.

## SUMMARY

Observations on 12 direct (diverticular) herniae and a study of the parietal layers of the ventral abdominal wall in the inguinal (Hesselbach) triangle in 268 body-halves show that:

1. Seven of the direct herniae were in the supravesical fossa and five in the middle inguinal fossa.

2. The possible influence of fossae associated with the urachus and obliterated umbilical arteries is discussed.

3. Direct herniae have been noted in the muscular and in the aponeurotic portions of the inguinal triangle. The rôle of weak fascial areas in the layering of the inguinal triangle is presented.

4. The course of a direct diverticular inguinal hernia is usually through the external abdominal ring. An enlarged external inguinal ring probably does not predispose to hernia unless there is associated with it a weakness of the other parietal layers.

5. The strength of the inguinal triangle depends mainly on the presence or absence of fossae in the peritoneum and the condition of the conjoined aponeurosis—is it muscular, aponeurotic, or fascial?

6. There is a definite need for autopsy, surgical and dissecting room reports on the association of direct herniae with peritoneal fossae.

It is a pleasure to acknowledge the coöperation of Dr. John Donaldson, of the Anatomy Department at the University of Pittsburgh, and to Dr. T. Walley Williams who made the photograph.

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# EXPERIENCE WITH CURARE IN ANESTHESIA

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THE USE OF CURARE as a supplement to anesthesia has gained a remarkable following since its introduction into medical practice in 1938. After the pioneer work of Gill,[1] and the use of the drug initially by neurologists and psychiatrists, Griffith,[2] at the suggestion of Wright, first used curare in patients during anesthesia to produce skeletal muscle relaxation and reported his results in 1942. Since that date, several hundred papers have appeared which are almost unanimous in acclamation of the drug. Almost no ill effects of the drug other than respiratory depression have been reported. It has been pointed out repeatedly that the use of curare to produce relaxation is no substitute for good anesthesia, with ample oxygenation and efficient removal of carbon dioxide. The importance of its administration by a physician who is aware of the need of immediate assisted respiration and is able to perform it promptly and adequately has been properly stressed.

Many questions remain to be answered, both in the laboratory and in the clinic. There is some disagreement as to the tone of the intestines following a dose of curare, and the proper treatment of the change in tone, if such is observed. There is some doubt whether a pharmacologic antidote, such a prostigmine, is needed in addition to the physiologic antidote-artificial respiration. Whether it is wise to use the drug in the presence of shock and hemorrhage is not known. It is possible that the postoperative incidence of atelectasis and pneumonia will not be decreased as much as expected because of the time necessary for complete recovery of the intercostal muscles and diaphragm. Many more clinical reports are needed to clarify this point. The signs of anesthesia, both with inhalation and intravenous drugs must be redescribed. It is exceedingly difficult to be certain of the state of unconsciousness when the action of all skeletal muscles has been depressed and the patient's trachea has been intubated as well. This fact has been made vivid to us by the observation of a patient, himself a surgeon, undergoing a lobectomy for bronchiestasis.[3] Anesthesia was induced with pentothal and curare, an endotracheal tube was inserted and the operation begun, with pentothal and curare added at intervals. Objectively, the anesthesia was highly successful, but the patient remembers vividly every detail of the last half of the operation, and was unable to communicate his discomfort to the anesthetist. Another question to be answered is that of the advisability of early ambulation in patients who have received curare in generous doses. Experience with a few unanesthetized patients who have been curarized to the point of marked respiratory depression, and then allowed to walk after one or two hours, with resulting severe muscle pains, suggests that ambulation on the day of anesthesia is inadvisable.

This report of 200 consecutive cases which received curare during anesthesia, since November, 1943, will answer none of the above questions but will

describe our experience with the drug in a teaching clinic. In all cases the anesthesia was administered by physician anesthetists after at least three months of an active residency. No one was allowed to use the drug unless he demonstrated a good working knowledge of the signs of anesthesia. He also must have demonstrated his ability to introduce an endotracheal tube under direct vision with rapidity and lack of trauma. The decision as to the selection of this drug for use in a certain patient was made in consultation with a senior anesthetist, but the dose and management of the complications were left to the resident. The drug used was "Intocostrin," marketed by E. R. Squibb and Sons, in a 2% concentration. The drug was usually stored in the refrigerator. The intravenous route was the only one employed. While a vein in the forearm or hand was the usual site chosen, the external jugular vein was frequently used. Introduced into infusion tubing near the needle, this solution was found to mix freely with saline, glucose or blood, but to form a precipitate with all pentothal concentrations. The rate of injection was rapid. The maximum action was almost always present in 60 seconds, while the duration of action varied greatly with the anesthetic agent, the plane of anesthesia when the drug was administered and the length of time that plane had been established.

Twenty different physicians administered curare in these 200 patients. The region of operation is listed in Table I.

TABLE I

| Region | Cases |
|---|---|
| Upper abdomen | 95 |
| Lower abdomen | 42 |
| Chest, intrapleural | 18 |
| Chest, extrapleural | 1 |
| Head and neck | 39 |
| Rectum and prostate | 4 |
| Extremity | 1 |

The anesthetic agents used are listed in Table II.

TABLE II

| Agent | Cases | No. Intubated |
|---|---|---|
| Ether | 127 | 81 |
| Pentothal | 42 | 31 |
| Cyclopropane | 24 | 12 |
| Spinal/$N_2O$ | 2 | 0 |
| Avertin/$N_2O$ | 3 | 0 |
| Spinal/pentothal | 1 | 0 |
| Procaine infiltration | 1 | 1 |
| | | 125 |

The principal reason for its use, as given by the anesthetist, is listed in Table III.

TABLE III

| | |
|---|---|
| Relaxation of the surgical field | 127 |
| Aid to intubation | 56 |
| To facilitate induction | 8 |
| To decrease respiratory movements | 4 |
| To control excitement during induction | 1 |
| To use less anesthetic agent | 1 |
| For demonstration purposes | 1 |

The dosage and anesthesia time are given in Table IV.

TABLE IV

| | Average Initial Dose | Average Total Dose | Average Anes. Time |
|---|---|---|---|
| Ether | 42 mg. | 52.3 mg. | 153 mins. |
| Pentothal | 82 mg. | 91.5 mg. | 50 mins. |
| Cyclopropane | 42 mg. | 77.7 mg. | 140 mins. |

TABLE V

RESPIRATORY EFFECTS OF CURARE

| | No Effect | Slight Depression | Moderate Depression | Marked Depression | Apnea |
|---|---|---|---|---|---|
| Ether (2, no data) | 69 (55%) | 4 | 23 | 14 | 15 |
| Pentothal (1, no data) | 33 (80%) | 1 | 2 | 1 | 4 |
| Cyclopropane (2, no data) | 12 (55%) | 2 | 1 | 0 | 7 |

In no case with ether or pentothal anesthesia, was the apnea planned. With cyclopropane, controlled respiration had been chosen as the method of choice in several cases, so that the apnea may not have been a result of overdosage of the drug, but rather, the result of technic used.

TABLE VI

CIRCULATORY EFFECTS OF CURARE

| | No Effect | Rise in Systolic | Fall in Systolic | Rise in Pulse | Fall in Pulse | Remarks |
|---|---|---|---|---|---|---|
| Ether (1, no data) | 93 (73%) | 12 | 10 | 5 | 1 | 1 arrhyth. 1 variable |
| Pentothal (2, no data) | 35 (87%) | 0 | 1 | 2 | 2 | |
| Cyclopropane (1, no data) | 20 (87%) | 1 | 1 | 1 | 0 | |

The anesthesia records kept during pentothal and curare anesthesia are not as accurate as those with ether or cyclopropane, for seldom were two anesthetists available, the operations were usually performed in the dark and the anesthetist was unusually busy. We feel that never is a record more important than the welfare of the patient.

TABLE VII

RETURN OF REFLEXES AT END OF OPERATION

| | Reflexes Back | Airway Left In | No Data | Dead |
|---|---|---|---|---|
| Ether | 71 (60%) | 46 | 9 | 1 |
| Pentothal | 29 (83%) | 6 | 7 | |
| Cyclopropane | 17 (80%) | 4 | 3 | |

OTHER COMPLICATIONS DURING OPERATION

| | |
|---|---|
| Hiccoughs | 3 |
| Profuse diaphoresis | 3 |
| Profuse secretions | 10 |
| Death from hemorrhage | 1 |
| Death during resuscitation following overdosage | 1 |

This last case deserves further description. A four-day-old female was admitted with deep jaundice and intestinal obstruction. Temp. 99° F., hemoglobin 21.8 Gm.; R. B. C. 5,620,000; W. B. C. 8,550. Rh negative; Wt. 2230 grams (4.9 lbs.) An infusion, and transfusion were given, a stomach tube was inserted, and a diagnosis of atresia of the jejunum was made and corroborated at operation, where a 10 cm. obstruction was found. An end-to-side jejunojejunostomy was performed. Because of the obviously poor risk of the patient, it was thought that curare might be ideal to quiet respiration enough to allow a satisfactory surgical field. No premedication was used. A few cubic centimeters of 1 per cent procaine hydrochloride was used for the skin incision. Ten milligrams of curare was the dose selected, and was given intravenously. Even during the administration, some respiratory depression was noted, but the full dose was given. Apnea ensued immediately. There was some difficulty in finding an endotracheal tube small enough for the larynx, so that pharyngeal oxygen insufflation was begun, with manual pressure on the chest. Finally, a woven cotton suction catheter was cut to a 3-cm. length and inserted into the trachea, and after suction, a gentle insufflation of oxygen was begun through a Y-tube. Observation and palpation of the chest showed that the lungs could be inflated easily by this method. However, oxygenation became poorer, in spite of a flow of only 100 cc. of oxygen per minute. It was felt that the lumen of the tube was too small to permit good exhalation, and there was not enough leakage around the tube even with manual assistance on the chest. The pulse rate fell from an initial 140 to 80, indicating a severe hypoxia. The endotracheal tube was removed, and a small face mask with bag attached, was substituted. A to-and-fro infant's canister was used for a few minutes, but the leakage around the stomach tube indicated that it was not necessary to plan for carbon dioxide absorption. Oxygenation improved markedly with gentle, intermittent pressure on the bag. The pulse rate rose to 120, where it remained for the next two hours and a half.

The operation was completed in 45 minutes. Three other attempts were made to return to an endotracheal air-way, but in each instance the condition of the infant was better with mask and bag inflation. To prevent overdistention of the stomach, the stomach tube was aspirated continuously. One hour and 50 minutes after administration of the curare, very slight contraction of the mylohyoid muscles could be felt. No diaphragmatic action at all could be seen, and no ventilation was produced by the contractions. After another 30 minutes, with no further improvement, a trickle of 100 per cent carbon dioxide was held near the face for a few seconds, without any result or change in condition. Ten minutes later, 0.120 mg. of prostigmine was administered intramuscularly, with no noticeable effect during the next 20 minutes. At this time, a medical student suggested rectal dilatation as a respiratory stimulus. We were surprised to find that the diaphragm contracted sharply and vigorously, but without producing any ventilation, for the vocal cords were tightly adducted during the stimulus. The patient was reintubated, and the stimulus continued. Irregular diaphragmatic movements continued, but the heart, which seemed

unaffected as long as the patient was well oxygenated, slowed down abruptly when rectal dilation was started, and failed during the next 30 minutes.

Autopsy revealed no other findings except bilateral bronchopneumonia, which had been present about two days. A sample of brain tissue was sent to the Toxologic Laboratory at Bellevue Hospital, which reported a content of 0.25 mg. of curare per 200 mg. of brain tissue.[4] We are at a loss to know how to interpret this result. It was not until many hours later that it was discovered from the chart that 1 cc., or 20 mg., had been administered instead of the 10 mg. planned.

### POSTOPERATIVE COMPLICATIONS

There were 13 deaths in addition to the two in the operating room. Six of these were following esophagectomy. Since the operative time averaged seven hours, and the doses of curare had been small, it was felt that they were unrelated to the use of the drug. Three deaths occurred after two weeks and are unrelated. One man died on the first day following suture of a perforated jejunum, and was found to have a fulminating peritonitis at autopsy. Another man of 70, following gastrectomy for carcinoma, developed a mild bronchopneumonia for two days, but was improved the next two days. He died suddenly at night on the fourth day. No autopsy was obtained, and his death remains unexplained. The 12th death occurred in a man, age 45, who had a previous laryngectomy for carcinoma. He developed a severe intestinal obstruction, with accompanying shock. Operation revealed no definite pathologic lesion. He was awake at the end of the operation, which lasted 110 minutes, and died three days later, still undiagnosed. The death of the 13th patient also remains unexplained. A 250-lb. man in good health underwent a ventral incisional herniorrhaphy with nitrous oxide-ether anesthesia. Seven point eight grams of avertin were given him for basal narcosis in addition to 12 mg. morphine and 0.0005 Gm. scopolamine six minutes before anesthesia, subcutaneously. This dose did not depress him unduly, and two hours later, 60 mg. curare was given because abdominal relaxation was not adequate. Moderate respiratory depression resulted but was easily treated because an endotracheal tube was in place. Ventilation was normal for the next 75 minutes. Circulation was excellent throughout the operation. His pharyngeal reflexes had returned at the end of a 355-min. procedure. Ten minutes after return to bed, he was found dead. Roentgenograms of the chest at this time showed normal lung fields. No autopsy was obtained. It is probable that respiratory obstruction was the cause of death.

In addition to the pulmonary complications mentioned above, there were two cases of atelectasis, and two of bronchopneumonia, all of which responded readily to treatment. The incidence of other complications, such as vomiting, urinary retention, headache, and cough was at least as low as in similar types of operations anesthetized without curare, and seemed lower.

Discussion.—The results obtained in the 25 tonsillectomies anesthetized with pentothal and curare were appreciably better than a parallel series of 25

cases without curare. The recovery in the group without curare was prolonged and marked by extreme restlessness, necessitating much more nursing care than is available on a nose and throat ward. With the use of curare, much less drug was used, and the patients were awake shortly after completion of the operation. It is imperative to perform a thorough topical spray of the pharynx before intubation with pentothal especially, and advisable when the combination of drugs is used. Two per cent butyn sulphate gave satisfactory results, although 4 per cent cocaine was used in a few cases. All tonsillectomy patients, in the adult group, are intubated.

Our experience with prostigmine has been too small for comment. Only three patients received the drug, in 0.5-mg. doses, and no effect was observed in any of the three. Either the dose was too conservative or the drug ineffective through age. We have felt that assisted respiration is much more important than drug therapy.

The main disadvantage to the use of curare, as we have observed it in this clinic, is the difficulty in teaching signs of anesthesia. Even without curare, the signs are often subtle enough. The demand for the drug during upper abdominal cases is increasing to such an extent that it may not be necessary to teach third and fourth planes of anesthesia. From the accumulating literature, it is becoming evident that there is minimal metabolic disturbance following the use of the drug, which justifies its use in such patients. A reëvaluation of the signs of anesthesia is in order. Curare, we feel, has already assumed a permanent place as a supplement to anesthesia, and as more experience is gained, even respiratory depression may be obviated to a large extent.

SUMMARY

1. A series of 200 anesthesias supplemented by curare is presented.

2. One death was related to the use of curare, and was due to accidental overdosage, and too vigorous resuscitation. It is suggested that the concentration of the drug be changed to 1 per cent (1 cc. = 10 mg.) to lessen the hazard of mathematical errors.

3. There were no complications in the postoperative period related to the use of the drug.

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# THIOURACIL IN THE TREATMENT OF THYROTOXICOSIS

## EXPERIENCE OF THE THYROID CLINIC OF THE COLUMBIA-PRESBYTERIAN MEDICAL CENTER

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IN 1925, shortly after the widespread use of iodine revolutionized the treatment of thyrotoxicosis,[8] the Thyroid Clinic of the Presbyterian Hospital was organized by two internists, Drs. W. W. Palmer and B. J. Sanger, and a surgeon, Dr. W. B. Parsons, Jr. Subsequently other members of the staff joined the group which eventually included several surgeons and internists, a surgical pathologist, a psychiatrist and an ophthalmologist. An effective follow-up system* made it possible to observe long-term results of various therapeutic approaches, and wherever possible the patient was followed by the attending physician or surgeon who directed the therapy. Some patients have been under observation for more than 20 years.

The publication of Astwood's[2] now classical paper in May, 1943, marked the advent of a new principle in the treatment of human thyroid hyperfunction; a multitude of reports have since confirmed his results,[5, 6, 9, 11, 14] It was felt that the Thyroid Clinic, with the data accumulated over years of iodine, surgical and radiotherapeutic control of hyperthyroidism would provide a proving ground for comparison of the new agent with older treatments. It is greatly regretted that Drs. W. B. Parsons Jr. and Lawrence Sloan, the senior surgeons, who were serving with the Armed Forces, were not present during the greater part of this study.

The administration of thiouracil† to patients with thyrotoxicosis was begun in August, 1943. Not all cases seen in the Thyroid Clinic were treated with this drug; most of the cases with toxic nodular goiter, and a considerable number of primary cases, were still prepared for operation with iodine. Economic and geographic considerations sometimes also made iodine and surgery the treatment of choice. The patients who received thiouracil therapy were, however, an unselected group.

* Acknowledgment is hereby made to Miss Retta Pinney, R.N., without whose untiring interest and effort this follow-up could not have been accomplished.

† The thiouracil used in these studies was supplied through the courtesy of Doctors B. W. Carey and Stanton M. Hardy, of the Lederle Laboratories.

The problem seemed to divide itself naturally into four parts, each the primary interest of one of the authors, and so discussed here: (1) Primary toxic goiter—thiouracil treated. (2) Recurrent toxic goiter—thiouracil treated. (3) Thyroidectomy following thiouracil therapy. (4) Pathology.

## PRIMARY TOXIC GOITER
### (*77 Cases*)

The 77 patients who comprise this group were seen either on the wards of the Presbyterian Hospital, or were referred from the general Medical and Surgical Out-patient Department to the Thyroid Clinic.[1] In addition to complete histories, physical examinations and routine laboratory studies, the work-up included blood counts, basal metabolic rate determinations, estimations of the fasting serum cholesterol, chest roentgenograms, and, when indicated, electrocardiograms. Thirty-four of the cases were hospitalized before thiouracil therapy was begun; the remainder were treated as out-patients. The series included 59 females and 18 males; there were 57 white, 18 colored, and two Chinese patients. Their ages ranged from ten to 72 years, the majority being in the fourth and fifth decades. Of the 77 cases, 73 had toxic diffuse goiter, three had toxic nodular glands, and there was one case of acromegaly with hyperthyroidism.

Thiouracil was given to each patient in an amount sufficient to last only until the next appointment. Toxic reactions were described in detail to the patient with instructions to stop the drug at once, and come to the Clinic should any suspicious symptoms appear. The drug was administered in divided doses, but no more than three doses per day were given to ambulatory patients, and no particular effort was made to have the intervals precisely equal. Our earliest cases were treated with 1.2 Gm. per day, but when it became apparent that 0.6 Gm. was equally effective, initial dosage was reduced to this level. Fifty-seven patients started with 0.2 Gm. three times a day. On most of this group white blood and differential counts were performed weekly, for the first eight weeks, then bimonthly for the next eight weeks, and at longer intervals thereafter. The results of the blood examinations were known to the examiner before the next week's program was determined. At the beginning of the study, frequent measurements of basal metabolic rate and serum cholesterol were made, but as the pattern of response became more familiar such frequent checks were no longer necessary.

The patients were urged to eat a well-balanced, high vitamin, high caloric diet, but no vitamin supplements, calcium, or other adjuvant nutritional factors were routinely administered. The great majority received no phenobarbital or other sedative medication.

Thyrotoxicosis was controlled in every case where thiouracil therapy was not prematurely discontinued. In general, the metabolic response, improvement in symptomatology, and the disappearance of evidences of thyroid hyperfunction was similar to that reported by other authors. The over-all results will be presented, with emphasis only on features of particular interest.

Subtotal thyroidectomy was performed on 39 patients and they will be considered later. It is noteworthy that 12 of the cases operated upon had been taking thiouracil for over 14 weeks. Most of these were originally treated in the hope of obtaining a permanent remission without surgical therapy, but requested thyroidectomy because of the uncertainty of the outcome with thiouracil alone and because of the trouble and loss of time involved in repeated Clinic visits, blood counts, basal metabolic rate determinations, *etc.*

Seven patients have been lost to follow-up. In each case, Clinic attendance was faithful until the evidences of hyperthyroidism had disappeared; after that, even with letter or social service inquiry, they failed to return.

In 14 patients thiouracil was deliberately discontinued.[3, 14] This was not done until the basal metabolic rate had been held within normal limits for six months or more, and the maintenance dosage before the withdrawal was 0.2 Gm. per day, or less.[3] One of this group was asymptomatic for over a year, and then had a recurrence which was treated, at his request, with iodine alone and surgery.* Four had a return of hyperthyroidism within six months. One of these was the patient with acromegaly. All the recurrences were readily controlled again with thiouracil.

Eight patients have been asymptomatic, six of these from one to two years, two from six months to a year. One other patient has been off the drug for two months only—too short a period to warrant any conclusion. Seven of these nine patients had moderately enlarged glands before therapy and some degree of enlargement persists.

The only death in the series was due to a primary carcinoma of the liver which occurred in a 38-year-old Chinese male. He died 18 months after the administration of thiouracil was started and seven months after the appearance of symptoms of carcinoma.

Treatment continues in 21 cases. One of these requires a maintenance dosage of 0.4 Gm. per day, 18 months after starting therapy.

The toxic reactions which occurred in this group have been included in the two large studies which have recently been published.[7, 12] They are briefly summarized here, and some noteworthy aspects reviewed. In ten instances these idiosyncrasies have been severe enough to make permanent interruption of thiouracil therapy necessary. In five cases, routine blood examinations revealed dangerous granulocytopenia in asymptomatic patients. The drug was immediately withdrawn in all. Four patients never became ill, and their blood counts returned promptly to normal. The fifth developed absolute agranulocytosis four days after the initial count, and later had angina. She made an uneventful recovery. The earliest reaction occurred three weeks after the administration of 0.6 Gm. each day, and the latest followed after 18 months of uneventful treatment, with numerous normal blood counts. In this instance, on a maintenance dose of 0.3 Gm. o.d. the count revealed only 15 per cent neutrophiles in a total of 1,750 white cells.

* This case, therefore, does not appear in Table III.

Five patients had miscellaneous early reactions, such as fever, rash, thyroiditis, *etc.*, which have been described in the articles cited. Each idiosyncrasy of this type was checked by the readministration of a pilot dose of the drug, with a return of the particular toxic reaction.

In four instances white blood counts below 3,500 were disregarded since they did not differ significantly from the patient's usual values. There were no untoward findings following continued treatment.

The results of thiouracil therapy have ranged from the extremely dramatic, with a fall of 40 per cent in basal metabolic rate and a 28 per cent increase in body weight in three weeks, to the quite unimpressive, when 11 months of therapy with a dosage of 0.6 Gm. daily still permitted mild thyrotoxic symptoms and a basal metabolic rate of plus 20 per cent. In this patient, another month of therapy without change in dosage reduced his basal metabolic rate to plus 6 per cent and freed him of all symptoms.

Ophthalmologic studies were carried out on most of these patients by Drs. Russell Nicholl and Noel F. Stow. These will be reported in detail in another publication. No dangerous progression of exophthalmos occurred with thiouracil treatment in this primary group.

## RECURRENT TOXIC GOITER

### (*30 Cases*)

It was recognized early after the introduction of thiouracil that the danger of agranulocytosis might limit prolonged treatment with the drug to those categories of cases where surgery with or without roentgenotherapy had failed or was inadvisable. A separate study was, therefore, made of a group of recurrent cases. The results of treatment for the past two and one-half years are reported here.

Thirty cases of recurrent toxic goiter have been followed. Five of these, four women and one man, were deemed suitable for operation, were prepared with thiouracil, and are discussed in the sections on surgery and pathology. Of the remaining 25 cases six were men and 19 were women. Ages ranged from 22 to 56 years.

In 23 cases the results of treatment were observed for considerable periods of time, *i.e.*, 18 for 2—2.5 years; three for 1.5—2 years; two for 9 months—1.5 years. In two others therapy was discontinued. One of these died on the 11th day after contracting agranulocytic angina, although showing evidence of recovery in the white cells, because of thrombosis of the internal carotid artery. One developed drug fever and could not be treated further, although followed in the Clinic. One of the women developed a carcinoma of the cervix during treatment.

White blood and differential counts were done at two-week intervals throughout the study. Basal metabolic rate and fasting cholesterol determinations were done on the same day as the blood counts early in the study, later every one or two months.

*Dosage.*—An initial dosage of thiouracil 0.2 Gm. three times a day was

used in all cases, but in several instances 0.4 Gm. three times a day was needed to reduce the metabolic rate. No failure to restore the basal rate to normal was encountered. Maintenance dosage of the drug varied from 0.1 to 0.6 Gm. a day, in divided amounts. Escape from a maintenance dosage that had been previously sufficient occurred eight times, as late as 14 months after the start of treatment. An increase in the dose readily controlled these latter.

*Toxicity.*—The toxic responses have been incorporated with a larger series discussed elsewhere.[7, 12] Agranulocytosis occurred four times in three patients, as late as eight months after starting treatment. One drug fever and eight leukopenias were enough to warrant interrupting the administration of the drug. Renewed treatment lowered the white count a second time in only one patient.

*Fasting Cholesterol.*—This determination was useful in estimating the response to thiouracil in the early stages of treatment, tending to rise above 300 mg. per cent. In the later period the basal rate appeared to reflect changes in thyroid function better than the cholesterol level.

*Exophthalmos.*—A significant progression of exophthalmos was noted only once, a 5 mm. advance in one eye to equal the exophthalmos in the other eye. This occurred during two years of treatment.

*Remissions on Stopping Treatment.*—The results of stopping therapy are discouraging. Treatment was discontinued 24 times in 19 patients (Table I). Remissions for a year were encountered in two patients, one after four months and the other after 1.5 years of treatment. A third patient showed borderline thyroid toxicity one year after discontinuing the drug, and is very probably reactivated. A fourth patient had a year of therapy and has been symptom-free for five months. The other 15 patients showed recurrence of thyrotoxicosis within from one to six months after discontinuance of treatment, most of them by the third month (Table II). In seven of these in which overactivity recurred, the drug was not discontinued until after one to two years of treatment. Thiouracil therapy controlled the overactivity on reinstitution in all instances.

TABLE I

SHOWING MONTHS AFTER STARTING TREATMENT AT WHICH THERAPY WAS DISCONTINUED

*(Basal metabolic rates were normal throughout after the induction period of from 2 to 6 weeks)*

| Months | Number of Cases |
|---|---|
| 0– 3 | 1 |
| 3– 6 | 6 |
| 6–12 | 10 |
| 12–18 | 4 |
| 18–24 | 1 |
| 24 or more | 2 |

## THYROIDECTOMY

### *(47 Cases)*

Forty-four cases were referred for operation between October, 1943 and January, 1946, and three were managed directly, making a total of 47. Of the

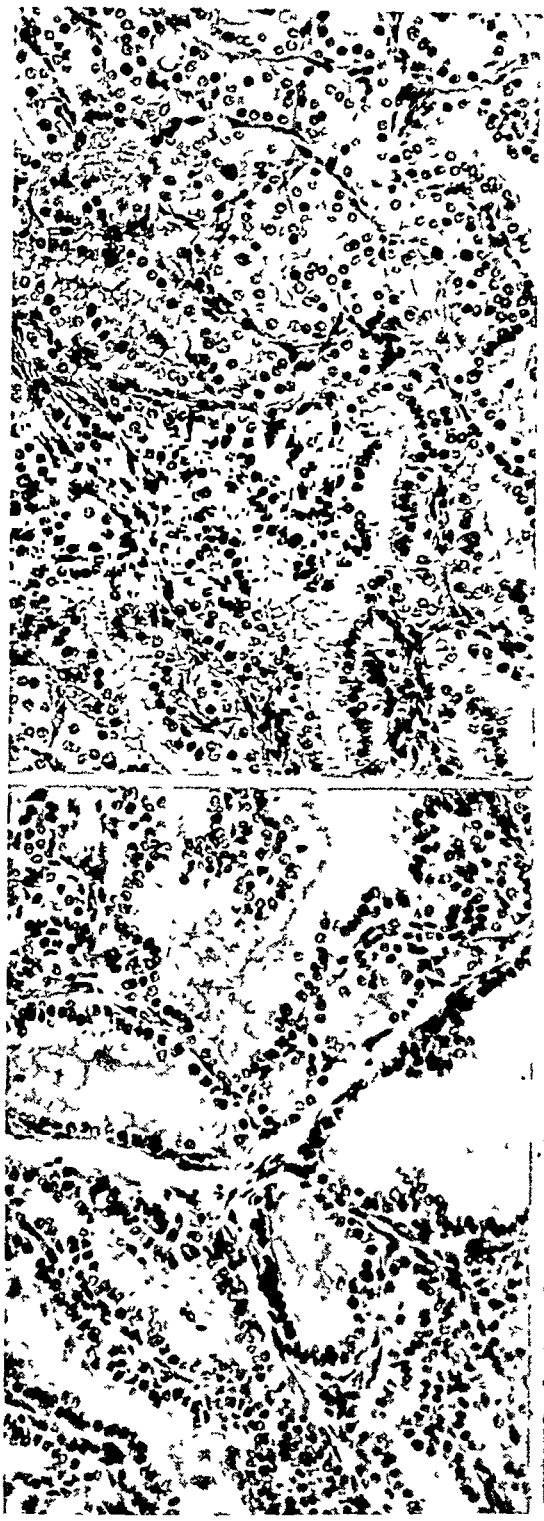


FIG. 1

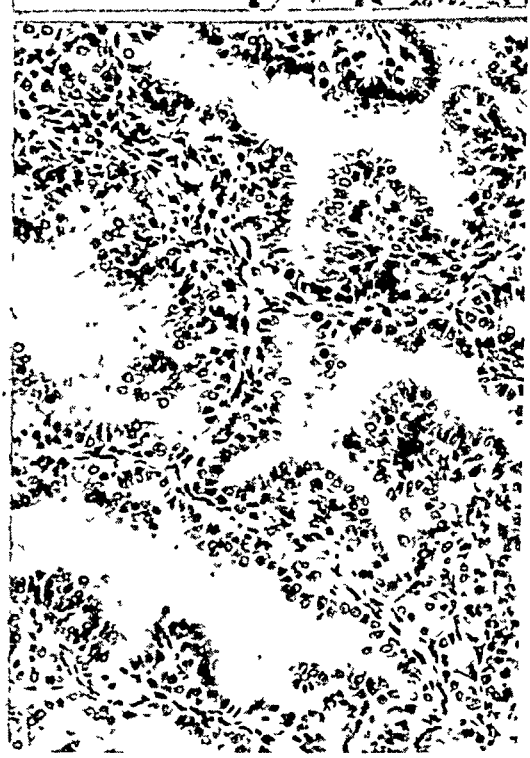


FIG. 2



FIG. 3

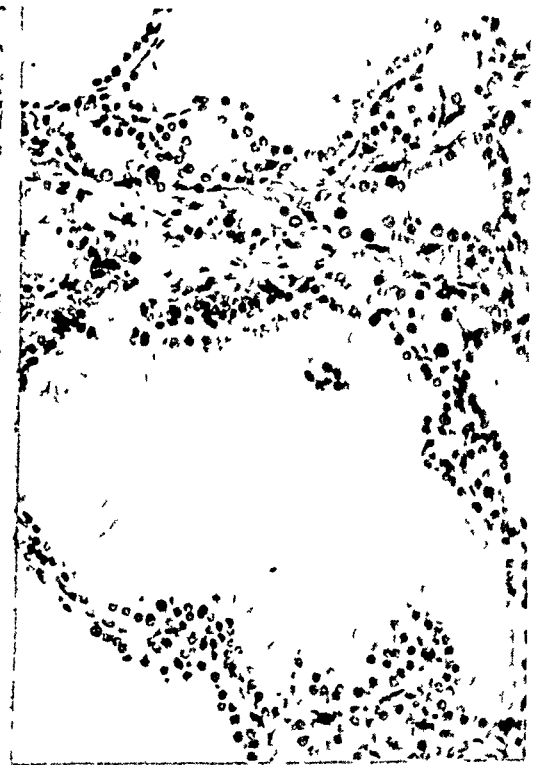


FIG. 4

TABLE II

SHOWING MONTHS AT WHICH RECURRENCE OCCURRED AFTER DISCONTINUANCE OF THERAPY

| Months | Number of Cases |
|---|---|
| 1 | 8 |
| 2 | 7 |
| 3 | 2 |
| 4 | 0 |
| 5 | 1 |
| 6 | 1 |

toxic diffuse glands, as will be seen from Table III*, 18 cases were prepared by thiouracil alone, six had iodine preceding thiouracil therapy, but, in essence, should be regarded as prepared with thiouracil, 14 had thiouracil supplemented with preoperative iodine, and four were recurrent toxic diffuse goiters. There were in addition five nodular goiters of which one was also a recurrence. It will be seen from the table that the preparation was variable, either because there were contraindications to the continuance of the drug, or because of the laborious nature of continued drug therapy. Where discontinuance was necessitated because of toxic reactions, the preparation for operation was not always adequate. When it was adequate the basal metabolic rate had returned to normal, symptoms had abated, and the pulse and weight gain were satisfactory. The introduction of iodine as an adjuvant is recent,[5, 10] and not as yet uniform, but the present plan is to give iodine for two weeks prior to operation and to discontinue thiouracil one week before the procedure.

*Operative Findings.*†—Unusual difficulty with hemostasis and unusual friability of the gland were encountered in some of these cases. It is impossible to assay this accurately, particularly when several surgeons, some less experienced than others—as in the case of the resident staff—are reporting their findings. The preoperative use of iodine has probably lessened the exces-

FIG. 1.—S. P. 86068. Moderate Thyrotoxicosis. Iodine 16 days. Considerable colloid. Marginal vacuolization. Papillary infolding.

FIG. 2.—S. P. 84810. Moderate Thyrotoxicosis. Iodine 16 days. Marked hyperplasia. Papillary infoldings. Fragmentation and disappearance of colloid.

FIG. 3.—S. P. 88452. Severe Thyrotoxicosis. Thiouracil 23 weeks. Diffuse extreme hyperplasia. "Classic" response. Compare with Fig. 4—28 weeks.

FIG. 4.—S. P. 93201. Severe Thyrotoxicosis. Thiouracil 28 weeks. Patchy moderate hyperplasia. Moderate late involutional changes. Compare with Fig. 3—23 weeks.

* This table has been deliberately modeled after Table I in the article by Moore, *et al.*, so that the two groups of cases could be compared.

† A number of these cases were under the care of Doctor J. M. Hanford who was the senior surgeon in the Clinic during the war years.

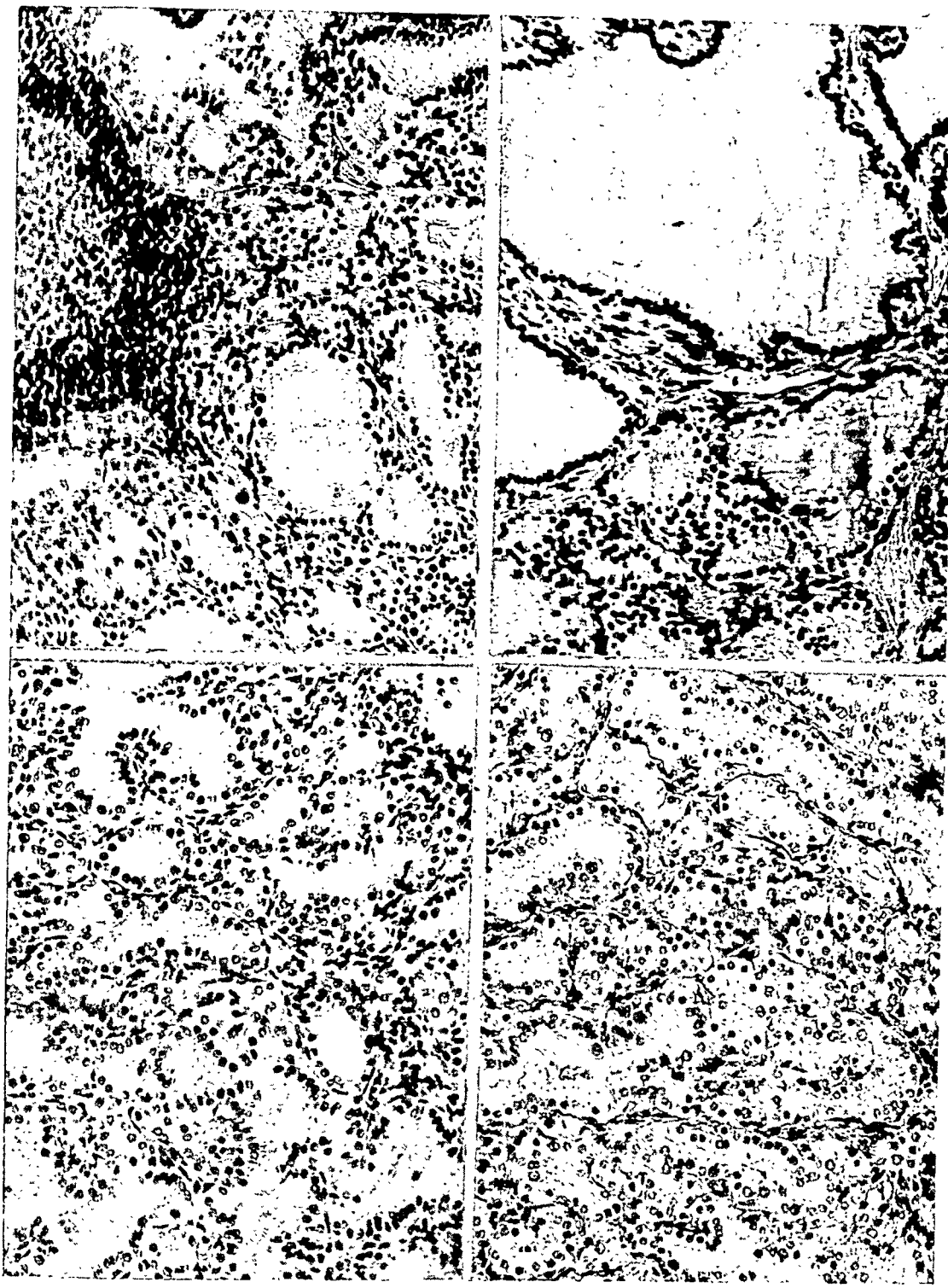


FIG. 8

FIG. 6

sive bleeding, although it is not possible to establish this point in so small a series. In the five nodular glands removed these technical difficulties did not arise.

*Postoperative Course.*—This was in general smooth, without thyrotoxic reaction. Full-blown "storm" is seldom a controversial finding, but the interpretation of lesser degrees of postoperative reaction is obviously often a matter of individual opinion. In ten of these 47 cases there were toxic reactions of varying severity. In seven of these cases this can probably be attributed to inadequate anteoperative preparation as described above. In one case in which a temperature rise to 105° F. developed the day following operation, considerable difficulty had been experienced in introducing an intratracheal tube during anesthesia. In spite of the height of the fever there was no concommitant evidence of "storm." The reaction was attributed to the onset of an acute upper respiratory infection and an ulcerative tracheitis. The remaining two cases, however, seemed to be well prepared for operation and yet one, with no previous history of cardiac difficulties, developed paroxysmal fibrillation on the first postoperative day, and the patient appeared definitely thyrotoxic. The other had a temperature rise to 103° F. within 24 hours, and also appeared quite toxic. The course was, in general, no different from the average severe case of thyrotoxicosis prepared on iodine alone. Moreover, this case had received iodine as an adjuvant measure for two weeks prior to operation which was not so in the other toxic case. It will be seen from the chart that there were three postoperative hemorrhages, whereas in the control 30 iodine-prepared cases, there was only one. In two of the three thiouracil cases the hemorrhage was not because of uncontrollable ooze but because of failure to ligate a major vessel—a definite technical error.

## PATHOLOGIC STUDIES

In an effort to correlate the gross and microscopic findings with the changes thought to be induced by the administration of thiouracil, 42 of the 47 surgical specimens were selected for study. The five nodular glands were omitted,

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FIG. 5.—S. P. 80248. Moderate Thyrotoxicosis—Recurrent. Iodine 7 days. Compare with Fig. 6 from the same patient 3 years later. Diffuse extreme hyperplasia.

FIG. 6.—S. P. 91490. Moderate Thyrotoxicosis—Recurrent. Thiouracil 7 weeks. Compare with Fig. 5 from the same patient, 3 years earlier. Patchy extreme hyperplasia.

FIG. 7.—S. P. 93121. Moderate Thyrotoxicosis. Thiouracil 10 weeks and iodine 10 days. Patchy slight hyperplasia. Diffuse late involution. Lymphoid follicles.

FIG. 8.—S. P. 92512. Moderate Thyrotoxicosis. Thiouracil 52 weeks. Moderate hyperplasia. Early involution.

because of the small number and the variable pathologic picture. The specimens studied are included in the table in which the surgical cases are charted. The duration of therapy, type of therapy and clinical course may be seen at a glance in relation to the gross and microscopic findings. There is no correlation as far as the latter are concerned with age, sex, duration or severity of symptoms before operation. The most hyperplastic glands in the group treated with thiouracil only occurred in some of the early cases when the dosage was larger than in those later in the series, but even so, extreme hyperplasia was found where the duration of treatment had been as short as 25 days or as long as 23 weeks. In general diffuse extreme hyperplasia, (*i.e.*, columnar cells with papillary infoldings, marked loss of colloid and marginal vacuolization of what remained), was observed in those glands which had had adequate thiouracil preparation and no other treatment. There were, however, exceptions even to this (Fig. 4).

These 18 glands prepared on thiouracil alone were compared with a control group of 30 prepared on iodine alone. It was somewhat surprising that the average weight of the tissue, where recorded, was found to be less in the thiouracil-treated group than in the group prepared with iodine, *i.e.*, 15 thiouracil treated glands, average 43.1 Gm.; 23 iodine treated glands average 50.8 Gm. In finer histologic detail changes in the colloid—fragmentation, change in staining, disappearance—were studied and found to be more marked in the thiouracil treated group than in those prepared with iodine. Marginal vacuolization and papillary infolding did not vary markedly in the two groups. Focal collections of lymphocytes, with or without germinal centers, appeared about equal in the two series. On first study it seemed as if the hyperplastic epithelial cells in the thiouracil group were paler and somewhat thicker, even when tall columnar. This characteristic can be seen in some of the photomicrographs (Figs. 3 and 6), but as a criterion this is not wholly reliable because of technical differences in preparation of the sections. It was almost impossible to judge accurately the vascularity in the fixed and stained preparations. It appeared, however, that the glands showing extreme hyperplasia in the thiouracil group were more vascular. Increase of fibrous tissue seemed about equal in the thiouracil group and the control.

No recognizable involutional changes were found in six of the 18 thiouracil-prepared cases. In the other 12 they were for the most part patchy and slight, but in some instances more advanced, notably in the gland which had had 52 weeks of consistent treatment (Fig. 8). An additional check on function was made by the preoperative administration of a tracer dose of radioactive iodine to two cases, (Case 1 in the toxic diffuse group, thiouracil preparation and Case 1 in the toxic nodular group, thiouracil preparation). Chemical analysis of the operative specimens revealed only a very small fraction of the radioactive iodine in the "thyroxin fraction." This is in accord with the findings of other observers.[9]

The unreliability of the histologic criteria of function is well illustrated by Figures 3 and 4, both thiouracil-treated glands with satisfactory response. The

one at 23 weeks shows what might be called a "classic" thiouracil response—extreme hyperplasia. The one at 28 weeks is a striking contrast. The explanation is not at hand.

## CONCLUSIONS

1. Thiouracil in this series has controlled the symptoms and signs of thyrotoxicosis in all cases and restored the basal metabolic rate to normal except when prematurely discontinued.

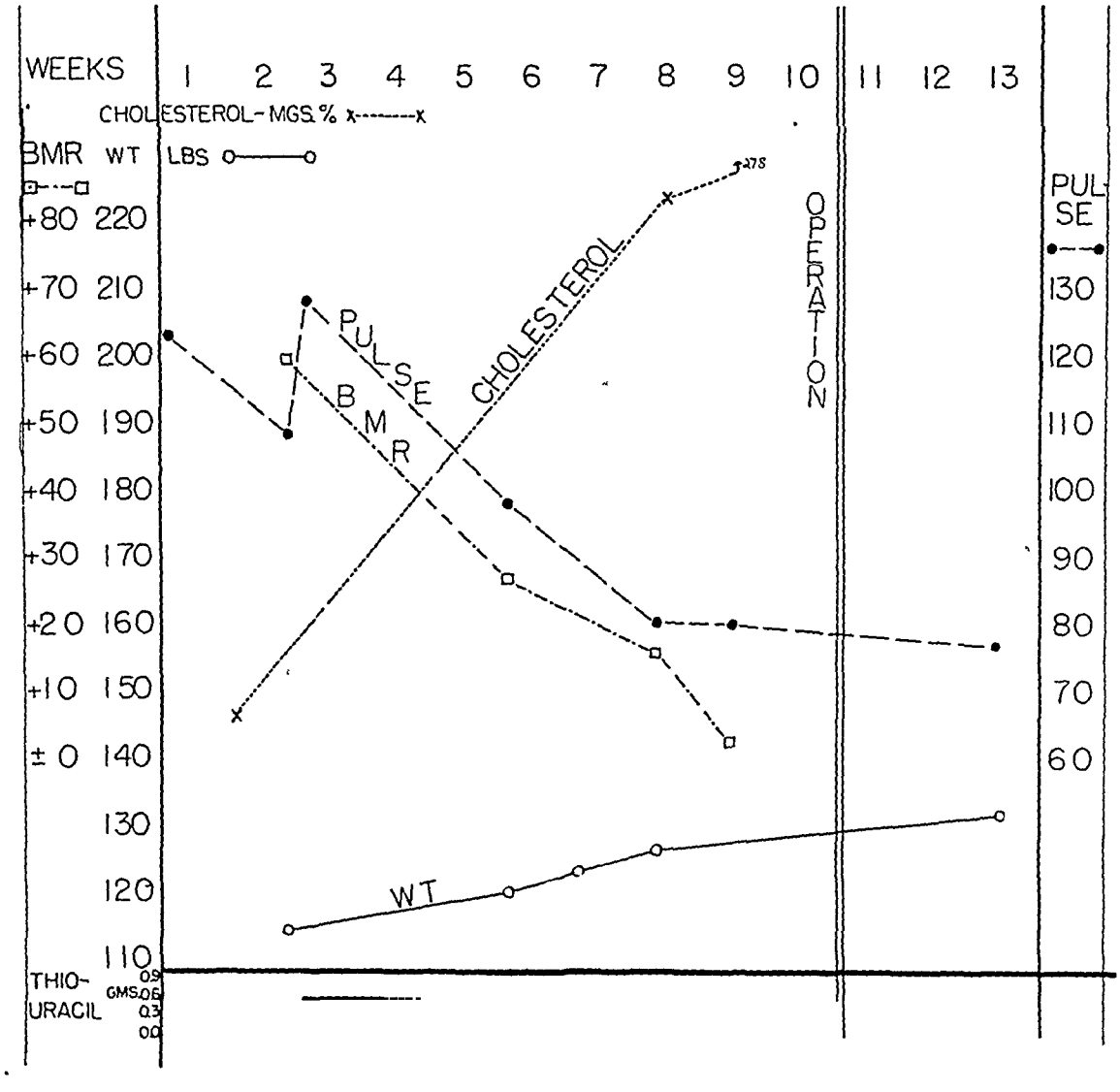



CHART I

CHART 1.—Case 7: Graph of satisfactory thiouracil response—Preoperative.

2. The incidence of "permanent" remissions obtained in primary thyrotoxicosis by the use of thiouracil is so small that we do not advocate it as the sole therapeutic agent.

3. Prolonged treatment with thiouracil in primary thyrotoxicosis should probably be reserved for the following categories of cases:

a. Those in which surgery has been refused, has been ineffective or is inadvisable.
b. Those in which malignant exophthalmos is feared.
c. Those which are in the adolescent age-group.
d. Those in which roentgenotherapy has been administered without benefit and where operation is not feasible.

4. As a preparation for operation the use of iodine alone is advocated for the average case of toxic goiter because of the present incidence of toxic reactions with thiouracil and the length of time required for preparation with this drug. (Should a related drug without toxic effects be successfully developed these conclusions might well be revised). Thiouracil can be used to advantage as preparation for operation in:

a. The poor risk cases such as thyrocardiacs or those with extreme thyrotoxicosis.
b. Patients who do not tolerate iodine or who require prolonged preoperative treatment.

5. Thiouracil therapy is promising in a selected group of cases with recurrence of symptoms after operation.

6. The permanent remissions in thiouracil treatment of recurrent toxic goiter are disappointingly few but the drug does offer a means of control of hyperactivity over long periods.

7. There is no constant correlation between the pathologic findings and the preoperative course, *i.e.*, duration, severity of symptoms and therapy.

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# EARLY POSTOPERATIVE AMBULATION

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EARLY POSTOPERATIVE AMBULATION has been practiced on the surgical service since August, 1944. This brief presentation is a review of 500 such cases compared with 500 similar cases which were left in bed the usual 10 to 14 days. The findings are comparable with the results from similar studies carried on in other clinics.

The postoperative care of the group allowed to walk early is as follows: Once the patient has fully recovered from anesthesia, he is put up in a high head-gatch and encouraged to move about in bed as much as possible. The next morning an abdominal binder is applied and the patient is helped out of bed. He stands with help and is encouraged to take a few steps. He is again helped out of bed in the afternoon and walks a little more. The following morning he is assisted to the bathroom and thereafter is allowed up and about as desired. These patients are not allowed to sit in wheel chairs for several days but are made to walk.

The distribution of cases is as follows: 92 gallbladder and common duct cases, 150 appendicectomies, 106 herniae, 31 partial gastrectomies, and 121 general abdominal cases. About 77 per cent of these cases were closed with silk, 11 per cent with gut, and 12 per cent with cotton or other suture material. A similar group of cases not ambulated was used for comparison.

In the ambulated group there was a total of 43 postoperative complications, as compared with 93 for the nonambulated group, or 50 per cent fewer complications. Bronchopneumonia has been reduced from 6 per cent to 3.6 per cent; atelectasis from 1.2 per cent to 0.4 per cent; severe postoperative distention from 20 per cent to 0.2 per cent; phlebothrombosis from 2.4 per cent to 1 per cent; catherizations from 3.8 per cent to 3.6 per cent. In all cases excepting those which developed phlebothrombosis the complications occurring in the ambulated group were milder and resolved more rapidly than those which occurred in the group left in bed.

We have found that the incidence of phlebothrombosis has been reduced in the ambulated group, but not eliminated. There have been two cases of phlebothrombosis which should be mentioned.

One was a case of acute appendicitis who was walking on his first postoperative day and who was allowed home on his sixth. That night he returned to the Medical Service with the typical symptoms and findings of a pulmonary infarct. Following bilateral vein ligation and a stormy course he recovered.

The second was a case of cholecystitis and cholelithiasis. There were no preoperative complications. Following operation she was allowed up on the

first day and was walking on the third day. On the evening of the sixth day she noted the sudden onset of chest pain and pain in her left leg. Deep shock and death rapidly followed.

Study of this group of 500 cases of early ambulation has brought to light the following important points:

1. There is a definite reduction of all postoperative complications.
2. Less medication and rectal treatments are necessary.
3. Less nursing care is needed.
4. There is a far more rapid return to normal of the bodily functions in the group that was allowed up early.
5. The improvement in the morale of these patients is tremendous and the majority of them have been much in favor of this form of postoperative care.
6. There has been no delay in wound-healing or serious wound-healing complications.
7. There has been no increase in the incidence of postoperative hernia.
8. There is a saving in time and money to the patient and a more rapid turnover of patients per bed per month.
9. Early postoperative walking is not to be advised as a blanket formula for all patients.

Complications which should be mentioned as contraindication are: Prolonged preoperative bed rest; cardiac insufficiency; recent coronary occlusion; shock; severe anemia; hemorrhage or fear of hemorrhage; the presence or suspected presence of thrombi or emboli; cholangitis; pancreatitis; insecure anastomosis; copious tamponade; and difficult hernial repairs in which the tissues for repair are of poor quality. Simple drainage is not a contradindication nor is the presence of a Miller-Abbott tube.

Finally, if a program of early ambulation is to be undertaken, the importance of carrying it out in detail cannot be emphasized too strongly. It is most important to see that these patients are up and walking, not sitting in wheel chairs for days. The optimum time to ambulate these patients is in the first 24 to 36 hours, before complications have occurred. Later than the third day, few if any benefits are obtained and, in fact, it would be better to keep them in bed 10 to 14 days, as before, than to allow them up after the optimum time has passed.

# THE EFFECT OF EVISCERATION UPON TRAUMATIC ABDOMINAL WOUNDS

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THE EXTRAPARIETAL PROTRUSION of an intraperitoneal organ through a traumatic wound of the abdominal wall is always an event of the first magnitude. Few abdominal injuries or catastrophes appear as urgent as the casualty whose wound permits loops of intestine to protrude outside the abdominal cavity. When the herniated viscera are visibly lacerated, transected, and traumatized, the occasion is even more pressing. Disruption of celiotomy wounds in civilian practice may present the same picture, and, in the operating room, the evisceration which may occur in a straining patient is always a matter of concern.

An opportunity to evaluate the effects of evisceration upon the mortality rate and the degree of shock in wounded individuals is made possible because of a relatively large series of World War II battle casualties.[1]

In a series of 3,154 traumatic abdominal and thoraco-abdominal cases operated upon in the Rome-Arno, North Apennines, Po Valley, Southern France, Rhineland and Central European campaigns, there were 312 cases of evisceration, approximately 10 per cent of the series. Evisceration, for the scope of this paper, is defined as the protrusion of an abdominal viscus, through a missile tract, to the outside of the abdominal cavity, the missile tract interrupting the continuity of all layers of the abdominal wall.

In this series each of the various intraperitoneal organs was eviscerated, and the frequency of the event, with reference to the presenting viscus, is shown in Table I.

The frequency of evisceration of an organ varied in regard to its mobility, volume, and in reference to the site and size of the tract. The small bowel alone, the omentum alone, the colon alone, and the small bowel and colon in combination, comprised 87 per cent of all eviscerations.

*Mortality.*—Case fatalities included were those cases which died within the echelon of the Field Hospital. Fatalities subsequent to evacuation were not included. A mortality rate, for this specific group, of 40.3 per cent was appreciably higher than the rate of 24 per cent for the total series of 3,154 cases.

A high mortality occurred when the colon was eviscerated. Such a situation was found, alone or in conjunction with other viscera, 73 times, with 42 deaths, a mortality of 57.5 per cent.

Thirty-two deaths, in 86 cases, a mortality rate of 37.2 per cent, occurred in the group in which the omentum alone was eviscerated. It should be stated,

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however, that in this category, while only the omentum was eviscerated, any of the intraperitoneal viscera may have been traumatized by the wounding agent. Twenty-four of these deaths took place within the first two postoperative days, and were attributed to the shock syndrome. This term is applied to those casualties which arrived in critical condition, did not improve appreciably

TABLE I

FREQUENCY OF EVISCERATION OF VARIOUS INTRAPERITONEAL ORGANS

| Viscus | No. | % Total | Deaths | Mortality Rate |
|---|---|---|---|---|
| 1. Small bowel | 123 | 39.4 | 43 | 34.9 |
| 2. Omentum alone | 86 | 27.6 | 32 | 37.2 |
| 3. Colon | 38 | 12.2 | 21 | 55.2 |
| 4. Small bowel and colon | 24 | 7.7 | 14 | 58.3 |
| 5. Stomach | 9 | 2.9 | 3 | 33.3 |
| 6. Liver | 7 | 2.2 | 3 | 42.8 |
| 7. Stomach, colon, small bowel | 5 | 1.6 | 2 | 40.0 |
| 8. Spleen | 3 | .96 | 0 | 00.0 |
| 9. Colon and liver | 3 | .96 | 3 | 100.0 |
| 10. Stomach and colon | 2 | .62 | 2 | 100.0 |
| 11. Liver and small bowel | 1 | .32 | 0 | 00.0 |
| 12. Spleen and stomach | 1 | .32 | 0 | 00.0 |
| 13. Spleen and colon | 1 | .32 | 0 | 00.0 |
| 14. No record | 9 | 2.9 | 3 | 33.3 |
| Total | 312 | 100.00 | 126 | 40.3 |

TABLE II

CAUSE OF DEATH IN 94 FATALITIES OCCURRING IN 226 CASES OF EVISCERATION, EXCLUSIVE OF OMENTUM

| Primary Cause of Death | Total | Per Cent | Day of Operation— 1, 2 Postop. | 3rd P.O. | 4th P.O. | 5th P.O. | 6th P.O. | 7th P.O. | 8th P.O. | 9th P.O. | Over | No. Rec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shock syndrome | 59 | 62.7 | 59 | | | | | | | | | |
| Peritonitis | 10 | 10.6 | | 2 | | 1 | 1 | 1 | 2 | 1 | 2 | |
| Anuria | 5 | 5.3 | | | 3 | 1 | | | 1 | | | |
| Pulmonary embolus | 4 | 4.2 | | | 1 | 1 | 1 | | 1 | | | |
| Pneumonitis | 4 | 4.2 | | 1 | | 2 | | 1 | | | | |
| Thrombosis inf. mesenteric vein | 1 | 1.06 | 1 | | | | | | | | | |
| Brain injury | 1 | 1.06 | 1 | | | | | | | | | |
| Intestinal obstruction | 1 | 1.06 | | | | | 1 | | | | | |
| Jaundice, edema | 1 | 1.06 | | | | | | | 1 | | | |
| No record | 8 | 8.5 | | 2 | 1 | 2 | | | | | 2 | 1 |
| Total | 94 | 99.74 | 61 | 5 | 5 | 7 | 3 | 2 | 5 | 1 | 4 | 1 |

following surgery, and died within the period limited by the second postoperative day. Two patients died on the ninth postoperative day from peritonitis. Both had combined perforations of stomach and colon. Of the remaining six deaths, four were ascribed to causes other than peritonitis. The cause of death was not recorded in two cases. The number of fatalities, two, 6.2 per cent of the 32 deaths, did not exceed the mortality rate of peritonitis in the over-all series of 3,154 cases. In the latter group the mortality rate of peritonitis was 12.04 per cent.[2]

The data indicated that the evisceration of omentum alone, was significant in reference to the severity of the intraperitoneal abdominal wound, and was

not significant, as an added contaminating factor, contributing to peritonitis. A subsequent allusion will be made to the effect of evisceration upon the state of shock.

*Cases Exclusive of Omental Evisceration.*—Exclusive of patients in which omentum alone presented, there remained 226 cases in which an abdominal organ protruded. Ninety-four deaths, a mortality rate of 41.5 per cent, occurred in this group. The primary cause of death is listed in Table II.

The ten deaths from peritonitis, 10.6 per cent of the total deaths within this group, was also no higher than the mortality figure for peritonitis for the over-all group (12.04 per cent).

The fatal incidence of pulmonary embolism was four, 4.2 per cent of all deaths in the group of 226 fatalities. Thrombosis of the inferior mesenteric vein occurred once.

*The Multiplicity Factor.*[3]—The numerical incidence of injury to abdominal organs, with reference to those wounded singly, or to those wounded in combination, as two, three, four, five or six, and alluded to as the multiplicity factor, is recorded in Table III. The omentum is not included as an organ in Table III.

TABLE III

RELATION OF MORTALITY TO NUMBER OF ORGANS INJURED

| No. of Injured Organs | Total Cases | Lived | Died | Mortality Rate, % | No Record |
|---|---|---|---|---|---|
| Without organs injured.. | 7 | 4 | 1 | 20.0 | 2 |
| 1 organ.... | 97 | 71 | 24 | 25.2 | 2 |
| 2 organs. | 106 | 63 | 38 | 37.7 | 5 |
| 3 organs. | 74 | 28 | 43 | 60.5 | 3 |
| 4 organs. | 16 | 4 | 11 | 73.3 | 1 |
| 5 organs. | 8 | 2 | 5 | 71.4 | 1 |
| 6 organs.. | 4 | 0 | 4 | 100. | 0 |
| Total | 312 | 172 | 126 | | 14 |

TABLE IV

TIME-LAG IN HOURS

226 CASES (EXCLUSIVE OF 86 OMENTAL EVISCERATIONS)

| | 0–6 | 6–12 | 12–18 | 18–24 | Over 24 | No Record |
|---|---|---|---|---|---|---|
| Total.. | 77 | 94 | 16 | 6 | 10 | 23 |
| Living.. | 48 | 52 | 11 | 4 | 6 | NR |
| Dead..... | 29 | 42 | 5 | 2 | 4 | NR |
| % mortality. | 37.6 | 44.6 | 31.3 | 33.3 | 40.0 | |

In Table III, a progressive upward trend of the mortality rate occurred, when the rate was plotted against the number of abdominal organs injured. This curve supports the contention that an index of the severity of a battle casualty was proportional to the number of abdominal organs injured.

*Time-lag.*—The elapsed time between wounding and surgery is referred to as "time-lag." The effect of time-lag upon mortality rate in this group of cases is reflected in Table IV.

MORTALITY IN RELATION TO TIME-LAG IN 203 CASES OF EVISCERATION OF ONE OR MORE ABDOMINAL ORGANS (OMENTUM EXCLUDED)

1944 - 1945

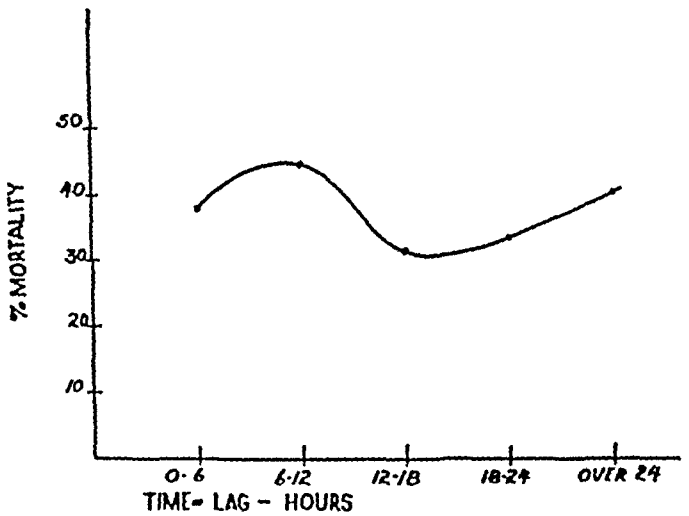



CHART I

MORTALITY IN RELATION TO TIME-LAG IN 37 CASES IN WHICH SMALL BOWEL ALONE WAS INJURED AND EVISCERATED

1944 - 1945

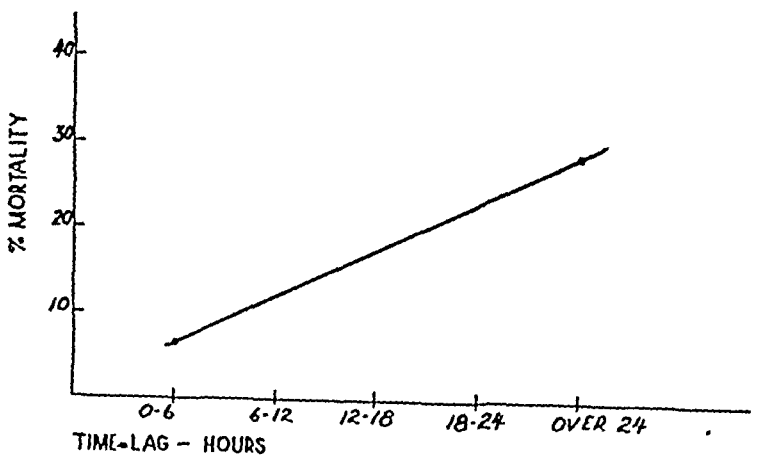



CHART II

The variable nature of this curve suggests that a large combination of factors affected it. Possibly not all of the wounded would have died within a ten-day period, if they had not been operated upon, a proposition which accounts for the survival of some in the long time-lag period, and certainly surgery had no effect in altering the lethal nature of the wound, in many of the severely wounded, although they had a short interval of time between wounding and surgery.

*Evisceration of the Small Bowel.*—A number of cases, involving the small bowel, presented an opportunity to consider the effects of evisceration, without the compounding effect of complex factors, because in 41 instances of the total of 123 patients in which the small bowel was eviscerated, it was the sole organ involved, and there were no complicating intra-abdominal injuries. In each of these 41 cases, the small bowel itself was wounded. Thirty-three patients lived, eight died, a mortality rate of 24.2 per cent.

Of the eight deaths, four died, within the first two postoperative days, of the shock syndrome. The rôle of peritoneal contamination, by small bowel content, may here have been manifested, because, save for the evisceration itself, none of the other complicating injuries was present. Two cases died of peritonitis on the 8th and 22nd days, respectively, one died on the 5th postoperative day, cause not stated, and the last died on the 5th postoperative day, of pneumonia.

The mortality rate of 24.2 per cent was higher than the rate in the same category, *i.e.,* small bowel alone wounded, in the 3,154 cases. In the latter series, there were 353 cases, with a mortality rate of 13.9 per cent.[4]

The average time-lag in these cases was short, 5.66 hours, indicative of the fact that these patients did not remain long in the shock ward before operation, for it was the widely held conviction that in this type of case delay in instituting surgery was futile, and the preoperative time of the administration of shock therapy was reduced to a minimum. The effect of time-lag upon mortality is shown in Chart 2. In Chart 2 only two points were plotted as otherwise numerically insignificant numbers of cases resulted.

*Evisceration Without Injury to any Abdominal Organ: Five Cases.*—The small bowel was eviscerated in four instances, the colon and the small bowel in one, without perforation of the lumen. The average time-lag per case was 20 hours. One fatality occurred, on the 4th postoperative day, of a massive pulmonary embolus.

Whether evisceration occurred at the time of, or subsequent to, wounding, was not indicated. However, in no instance, whatever the actual duration of the evisceration, did such a case exhibit the signs of clinical shock, either on arrival at the Field Hospital, or during the subsequent postoperative course.

*The Wounding Agent and the Site of Evisceration.*—In 171 patients the wounding agent was a shell fragment, in 97 a small arms bullet, in 31 a mortar, bomb, grenade, or mine fragment, and in 13 instances the agent was not recorded.

Evisceration, on occasion, occurred at the wound of entry, if the missile

was large enough. More frequently it was found at the wound of exit. In some cases, a wide-open tract existed between entry and exit wounds.

A chart of the site of evisceration of abdominal organs, without reference to omentum, reveals the upper abdomen involved 75 times, the lower abdomen 68 times, the left flank 28 times, the right flank 13 times, the left chest ten times, the right chest three times, abdominal site not specified 23 times, right back twice, left sacral region once, left buttock once, no record once.

## SUMMARY AND CONCLUSION

1. Three hundred and twelve cases of evisceration were recorded; 226 of these were of an abdominal organ, 86 were of omentum alone.

2. The group mortality was 40.3 per cent.

3. Evisceration of abdominal organs occurred in five instances without other abdominal injury. No clinical shock was present in these cases.

4. The wounding agent in slightly over half the cases was a shell fragment.

5. Mortality appears to bear a definite relationship to the number of intra-abdominal organs injured.

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# ORTHOPEDIC SURGERY IN THE EUROPEAN THEATER OF OPERATIONS

A BRIEF RÉSUMÉ

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THE PROFESSIONAL SERVICE Division of the Surgeon's office of the European Theater was established in August or September of 1942 under Major General Paul A. Hawley as Chief Surgeon and Colonel, later General, Elliott Cutler as Chief Surgical Consultant and Colonel William Middleton as Chief Medical Consultant for the Theater. Senior consultants for the Theater in all the various medical and surgical specialties were soon added. The first Senior Consultant in Orthopedic Surgery was Colonel Rex Diveley, who served as such from September of 1942 until the middle of May, 1944, when he was relieved of this assignment to devote his full-time to the Rehabilitation Division. The writer arrived in the Theater on D-Day minus 20—or about three weeks before the invasion of the Normandy beachhead—to assume the duties of Senior Consultant in Orthopedic Surgery. A tour of duty of one year at the Station Hospital at Fort Jackson had afforded an adequate background of the injuries incident to training at a large infantry post. Nine months as Orthopedic Consultant for the Fourth Service Command, with its 131 Station and 11 General Hospitals offered further opportunity to become familiar with the bone and joint problems found among the soldiers in training and returned from overseas. The earlier battle casualties with compound fractures and amputations arriving from North Africa, Italy and the Pacific were seen. At that time the vast majority of these compound fractures had been treated by the Orr-Trueta method, which left much to be desired. Returning amputees usually had not been subjected to skin traction and exposed bone ends were all too commonly encountered.

It was apparent to all surgeons of the various Theaters that there was room for improvement in the care of battle casualties with wounds involving bones and joints.

The newly arrived Senior Consultant in Orthopedic Surgery was handicapped by a lack of knowledge of the hospital and personnel situation in the Theater. Time was pressing, since the invasion was about to burst momentarily. In a period of approximately three weeks, in company with Lt. Col. William J. Stewart, who had served as assistant to Colonel Diveley between 40 and 50 hospitals were visited and the neophyte was indoctrinated to the extent that time and other circumstances allowed. Our headquarters were then in Cheltenham, later briefly in London, and even more briefly at Vallognes on the Normandy beachhead, and, finally, in Paris. The duties of a consultant who serves as eyes and ears for the Chief Surgeon and as teacher and adviser to the younger surgeons who are actually taking care

of the wounded, carries him on a constant round of visits to the various medical installations of all echelons from Field Hospital, and occasionally even further forward, back to the fixed hospitals. How many thousands of miles we covered by plane, jeep, command, or in rare instances staff car, will never be accurately known.

### PRE D-DAY ACTIVITIES OF THE ORTHOPEDIC SURGEONS IN THE THEATER

The orthopedic or traumatic surgeons were a fortunate group in the Army, in that they were always busy and, therefore, on the whole, contented. The increasing Army in the United Kingdom that was training so strenuously for the invasion had many injuries of varying severity. The Air Force stationed for the most part in East Anglia sustained battle casualties from the time they became operational, and there were many compound fractures to treat.

During this period of Army training, the Medical Corps had its training program. Classes were held constantly for instruction of the officers and enlisted men. Plaster of paris technic was taught continually. There was unanimity of opinion regarding most of the plaster of paris circular splints intended for the transportation of the wounded. The Tobruk splint was the single exception. This utilization of a full-ring Thomas splint, with adhesive traction and plaster of paris reënforcement, was enthusiastically recommended by our British colleagues for transportation of compound fractures of the femur, and prior to the invasion its application was taught and advocated. Surgeons returning to the Theater from the North African campaign reported that this splint was far from satisfactory, stating that a plaster of paris spica was superior in every respect. As time passed we became more firmly convinced that the plaster of paris spica splint from the knee of the sound leg and from the toes of the fractured leg, reënforced by a posterior strut, afforded the safest and most comfortable means of immobilization of the fractured femur while in transit.

The Chief Surgeon, aided by his consultant staff, prepared a Manual of Therapy for the E.T.O. This was issued in May of 1944. This small volume contains a good deal of sound basic medicine and surgery and certain technics of treatment are described. The surgical authors were handicapped by the fact that prior experience in the case of battle casualties was limited, and in some instances nonexistent. This manual of therapy was supplemented from time to time by circular letters from the office of the Chief Surgeon as experience was gained. When V-E Day arrived, we had established a satisfactory technic for the care of battle casualties with bone and joint injuries, and all that remained was to find and place the surgeons equipped or trained to carry it out. This brings us to the next problem.

*Personnel:* The earliest hospitals to arrive in the Theater were affiliated units, well-staffed General, Station and Evacuation Hospitals, bursting with medical and surgical skills. Each of these early hospitals had from two to four or five officers trained in bone and joint surgery. As time went on and

the Army grew, many other hospitals were added, until, finally, there was a total of 260 hospitals in the Theater. Of these, 143 were 1,000-bed General Hospitals. The orthopedic requirements for these hospitals by Table of Organization was approximately a total of 446 medical officer specialists (3153) with a rating of "B" or "C," which was supposed to indicate full civilian training and some experience in civilian practice. To produce this number of specialists would have required a black tail coat, a silk hat and a wand. There were, in June, 1944, approximately 820 diplomats of the American Board of Orthopedic Surgery. Three hundred and one of these entered the armed services and some 63 were in the E.T.O. Six of these were immobilized as consultants or commanding officers, *etc.*, or had been returned to the Zone of Interior, so that only 57 were available for the actual care of the wounded. To supplement these "elder statesmen," there were some 95 officers who had had partial civilian training in orthopedic surgery and 85 general surgeons who had had training in traumatic surgery. The remaining officers who filled the additional 175 positions, with a specialist rating in orthopedic surgery, had received their entire training in the Army. It was a matter of grim necessity to plunder the original affiliated units, rich in trained personnel, to supply those hospitals arriving later with undertrained officers or often none capable of assuming the duty of Chief of Orthopedic Section. Since our affiliated units formed less than ten per cent of the total hospitals, the inroads on these units were heavy and constant. There was, of course, an obvious end to this sort of business of dilution of the talent. When V-E Day arrived, the sanity of the Senior Consultant in Orthopedic Surgery was just preserved, as there were some six or eight newly arrived hospitals calling for an orthopedic specialist, with none in sight. With the cessation of hostilities these frantic cries could finally be answered —"so what"? The amazing fact remains that so much creditable surgery was done with so little, relatively well-trained personnel available.

An interesting and significant wound study was made prior to D-Day in East Anglia, where Air Force casualties were received. Three parallel groups of wounds were treated as follows: (1) Adequate débridement and immediate primary closure. (2) Adequate débridement, immediate primary closure and sulfonamides. (3) Adequate débridement, immediate primary closure and penicillin. There was no essential difference in the healing in these three groups. The low incidence of infection was almost identical in each group. The one factor each group had in common was the surgical treatment and the study pointed unquestionably to the fact that surgical treatment was of paramount importance. It was of course obvious that no parallel regarding immediate primary closure of wounds existed between the Air Force personnel, wounded at high altitudes in clean surroundings, with ample opportunity to bathe, and the infantrymen, who, unwashed, in dirty clothes, were to be wounded on the heavily manured soil of France and the low countries. To close immediately wounds under these latter conditions would have been utter folly.

The Medical Corps set up to service the invasion was carefully planned. Surgical teams were assigned to the LST's and other transports that would return the wounded. Field Hospital platoons were set up on the far shore within a few days. The first Evacuation Hospitals were set up within a week after the beachhead was established.

The fixed hospitals in the United Kingdom were emptied of all except urgent cases. Surrounding the ports of embarkation there were some 15 of these fixed hospitals, which were designated as Transit Hospitals, and served for some six weeks or longer as Evacuation Hospitals for the wounded which were transportable from the far shore. These evacuable wounded had mainly extremity wounds, about half of them with compound fractures

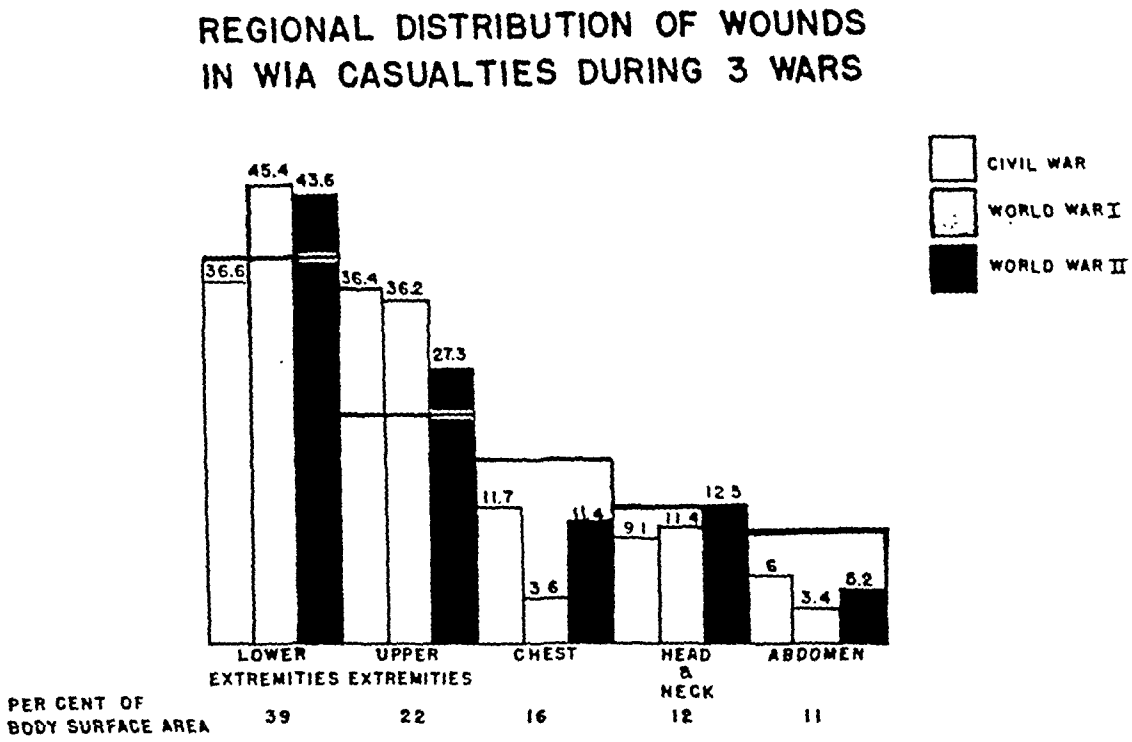



CHART I.—A table furnished by the Office of the Surgeon-General, Professional Service Division.

This comparison of the wounded in our three major wars is of great interest. The great preponderance of extremity wounds in each war is shown, 73 per cent in the Civil War, 81.6 per cent in World War I, and 70.9 per cent in World War II. Since approximately half of the extremity wounds involve bones or joints, it will be seen that between 35 per cent and 40 per cent of all battle casualties require the service of a bone and joint surgeon. Surgical personnel of all Army hospitals during hostilities should be set-up with this in mind.

The wounded and killed in action are doubtless hit in the various areas of the body in direct proportion to the per cent of total body-surface area which any part represents. These percentages of body-surface areas are indicated on the figures below the chart. It will be noted that there is a tremendous surplus of survivors in the extremity wounds and an equally marked deficit of survivors in the chest and abdominal wounds, as would be expected. The abdominal and chest wounds are apt to be immediately fatal due to massive hemorrhage.

It is interesting to note that in World War I the surviving chest and abdominal wounds were far below both the Civil War and World War II. This doubtless means that first aid and surgery had failed to keep pace with the enormously increased destructive force of the high explosive shells and high velocity small arms fire. The balance was restored in this war, despite even greater havoc and destruction wrought by the missiles used.

(Chart 1). Primary surgical treatment was administered in these Transit Hospitals, and 12 to 36 hours later the wounded were evacuated to other fixed hospitals for more definitive treatment.

The first of the fixed hospitals to accompany the invading force was opened on the far shore on August 1, 1944. The fixed hospitals which remained in the United Kingdom had, on the whole, excellent facilities and splendid equipment, and above all a stable set-up. It was to these hospitals that the bone and joint casualties, requiring a long-holding period, were evacuated.

The first fixed hospitals which moved to the continent in Normandy were under tentage. Many of these hospitals moved to a second or third site as the Army advanced. Most of them were under permanent shelter during the winter. Their facilities were for the most part not as desirable as those which they left behind in the United Kingdom, but they managed to improvise in an amazingly efficient manner. From the standpoint of the orthopedic or bone and joint surgeon, an assignment in the United Kingdom offered greater opportunity for long-time contact with bone and joint casualties than did service in the continental hospitals which served mainly on a transit basis, evacuating the compound fractures and amputees to the United Kingdom at the earliest possible moment. Only if evacuation had been or seemed likely to be unavoidably delayed beyond the optimum period for the use of skeletal traction (*i.e.,* within 21 days after wounding), were these continental hospitals permitted to treat these long bone fractures.

*Air evacuation* from the continent to the United Kingdom was started within the first week of the invasion and a series of Air Transit Hospitals were set up near Swindon to receive these casualties. This air evacuation, which is ideal, continued and grew in importance until finally the great bulk of the patients were transported within the Theater by this means. During December and January, the period of heavy fogs, air evacuation bogged down almost completely due to the weather. This weather "road block" is unavoidable and must always be considered.

### CARE OF THE WOUNDED WITH BONE AND JOINT CASUALTIES

1. *First Aid:* So much has been written about the care of the wounded in hospitals and so little acknowledgment has been given to the devoted, skilful care which our wounded received from the corpsmen and officers at the battalion level. Many of our records state that the wounded were dressed and on the way back within 20 minutes to an hour after wounding. The great bulk of this was done by medical enlisted men. A large number of these medical soldiers and officers gave their lives in attempting to secure the high standard of care which was set for our wounded.

*Splints:* Compound fractures of the femur and tibia and fibula were immediately placed in the Army leg splint (a half-ring Thomas splint) with a boot strap to secure traction. This boot strap is dangerous and if applied for more than two or three hours may cause pressure necrosis over the dorsum

of the foot. Adhesive traction should be substituted if prolonged use of this splint is necessary.

For compound fractures of the foot and ankle, the well-padded wire ladder splint was used. Upper extremity compound fractures were most comfortably and effectively treated for transportation by slings or swathes. The Murray-Jones splint is dangerous to circulation and its use was pretty universally condemned.

2. *Resuscitation:* At the battalion level, plasma was available and whole blood was administered at the clearing station. It was quickly learned that whole blood alone could serve as adequate replacement where there had been massive hemorrhage. Blood was employed extensively in the treatment of these wounded at all medical installations from the clearing station to and including the General Hospitals.

3. *Army Hospitals:* The bone and joint casualties for the most part are considered transportable, so they were sent to the Evacuation Hospitals while the nontransportable abdominal and chest wounds were treated at the Field Hospitals. Primary surgical treatment was instituted in these Evacuation Hospitals.

*Wound Excision or Débridement:* This is easier to describe than to achieve. All possible skin should be preserved and only that obviously necrotic should be excised. The wound should be opened with adequate longitudinal incisions and exposure of underlying tissue with adequate retraction secured. A peep-hole débridement invited subsequent infection. To aid exposure and avoid any tension, the fascia should be divided longitudinally and transversely if necessary. All dead or damaged muscle or fascia must be excised, removing all dirt and available foreign bodies. All bone should be preserved. Even completely loose fragments will heal and amalgamate with the general callus if skin coverage is secured by delayed primary closure and infection does not ensue. The wanton removal of all loose bone in many instances means a complete gap or loss of bone substance which can only be substituted for by subsequent bone graft. Many of these compound fractures with numerous completely detached fragments of bone heal completely. Occasionally one or two fragments may sequestrate before healing ensues. Even if considerable sequestration takes place, the situation is preferable to an immediate complete excision of all loose bone, resulting in nonunion with loss of substance and the endless bone grafting that is inevitable.

*Dressing of Wound:* These compound fractures should be dressed with fine-mesh plain gauze laid over or into the wound. "Packing" of these wounds with vaselined gauze prevents drainage of blood and exudate which is inevitable and invites infection. These wounds which are adequately treated surgically, properly dressed and incased in circular plaster of paris splints and arrive with dressings undisturbed at the Communication Zone Hospitals, are ideal for delayed primary closure. There is a saying that many a patient has been bandaged to death. It is a firm conviction among those of us who observed these wounds that frequent dressing means inevitable contamination of the

wound and that the contaminated or infected wounds were perhaps more frequently infected by subsequent dressings than by the original wounding agent. Those surgeons who employed a meticulous instrument technic and wore a mask had a far higher percentage of successful closures than did those who were careless in their treatment of the wounds. Eternal vigilance and careful attention to seemingly small details paid handsome dividends in wound healing.

*Chemotherapy:* Those wounded with compound fractures and amputations invariably received penicillin and/or sulfadiazine from the time of primary surgery. Local use of these agents was quickly abandoned except to instill penicillin into a closed joint cavity or into the pleura. It has been quite definitely proved that in most instances penicillin is preferable and that it acts best alone.

*Splinting of Compound Fractures for Transportation:* Circular plaster of paris splints were prescribed, of varying types for each of the long bones involved.

1. Compound fracture of tibia and fibula—a splint extending from toes to groin.

2. Compound fracture of femur—a plaster of paris spica bandage extending from the toes of the wounded leg and from the knee of the sound leg, reënforced with a posterior strut, leg-spread no more than the width of the litter.

3. Compound fracture of forearm—a circular plaster splint extending from behind the metacarpal heads to the axilla with the wrist in slight dorsiflexion and elbow at right angle.

4. Compound fracture of humerus—a plaster of paris shoulder spica or plaster of paris Velpeau splint. In no case can the arm be abducted widely because of the limited space in ambulance, plane or hospital train.

All of these circular splints must be split to the skin and slightly spread to allow for swelling in transit. Failure to observe this rule made the responsible officer subject to disciplinary action. There were reported losses of extremities due to unsplit plaster splints from other Theaters prior to D-Day, so this Theater was able to profit from the experience of others and insist on this rule.

The Army hospitals were not held responsible in any sense for reduction of these compound fractures. That was a function reserved for the Communication Zone hospitals.

### FIXED HOSPITALS IN THE ZONE OF COMMUNICATIONS

*Delayed Primary Closure of Wounds:* Here begins the definitive surgical treatment of the casualties with wounds involving the bones and joints. Delayed primary closure of these wounds in increasing numbers, as time went on, was the outstanding improvement in the care of these casualties. The idea of delayed primary closure of wounds is not new. It was practiced with success to a limited extent during World War I, but it was pretty well forgotten

unfortunately, as most of the lessons of military surgery are apt to be. They gather dust in a number of massive volumes, called in our particular case the Surgeon-General's history. The new crop of military surgeons usually have to learn all over again the hard way. At the outset of this war, our surgeons were dominated by the closed-plaster technic of treatment of compound fractures. This invites infection of bone and soft tissue and healing ensues slowly by second intention, with massive granulations which develop into scar tissue. Most of the earlier casualties with wounds involving bones and joints were returned to the Zone of Interior with their wounds suppurating under circular plaster splints. So firmly ingrained was the idea of closed-plaster technic, that it was not a little difficult to persuade the medical officers at first to attempt closure of these compound fractures. Within a month or six weeks after the invasion started, delayed primary closure was fairly completely accepted, and with experience it became increasingly successful.

The optimum time for delayed primary closure by suture or split-thickness skin graft is three to five days after wounding, and any time up to ten days is considered early. At this period the wound edges are mobile and the skin can readily be drawn together. After ten days there is some granulation tissue and new epithelium to be excised with some undercutting of the skin edges in order to secure approximation. A careful secondary débridement or a few days of wet dressings may be required prior to the later attempted closure. This closure by suture is accomplished by widely-spaced, deeply-placed nonabsorbable sutures without tension. Hemostasis must be secured, and at times a small drain is left in the wound for 24 to 48 hours. No attempt is made to secure a cosmetic result.

If the delayed primary closure is successful, the advantages which accrue are manifold—underlying exposed bone is conserved and healing of bone and soft-tissue is accelerated. Repair of divided peripheral nerves, open reduction of fractures, bone grafts where indicated, may all be performed at an early period. Convalescence is shortened. In an effort to determine the success of this form of treatment, 5,042 compound fractures, excluding bones of the face and skull and spine with spinal cord injury, were studied at the 15th Hospital Center between D-Day and November 15, 1944, a 4.5-month period. The bones of the lower extremity were involved in 2,614 instances and those of the upper extremity in 1,895. The long bones most frequently fractured by various missiles were the tibia (757), humerus (702), and femur (684), in that order and number.

Delayed primary closure was attempted in 2,393 patients, by suture in 2,087, by skin graft in 236, and by combination of suture and skin graft in 70. Skin grafting was by split-thickness free grafts and also by pedicle grafts where loss of bone and soft-tissue was considerable.

The results obtained in these attempted closures were as follows:

1. *Complete success*—healing by primary intention occurred in 1,592 cases, or 66.53 per cent of the total.

2. *Partial failure* occurred in 640 cases, or 26.74 per cent of the total.

Those rated partial failures showed a small sinus, a stitch abscess, or partial loss of a skin graft. All but a very few of these wounds healed by a second suture or skin graft or spontaneously and were classed as healed when the patient left the hospital. This means that a total of 93 per cent of the patients upon whom closures were attempted left the hospitals with their wounds healed.

3. *Complete failure* occurred in 161 cases, or 6.73 per cent of the total. This means an entire breaking open of the wound or the development of a soft-tissue infection or osteomyelitis, which necessitates wide surgical opening.

Further follow-up on these attempted delayed primary closures of wounds performed in the European Theater after return to the Zone of Interior was furnished by the Office of The Surgeon-General. A small series of 34 compound fractures of the femur, tibia, fibula and humerus, treated in the European Theater by delayed primary closure of their wounds were reported by the Ninth Service Command as follows: The delayed primary closure was successful in 73.5 per cent of the cases and the incidence of osteomyelitis was 14 per cent. A similar-sized series of compound fractures upon whom no attempt at closure had been made was reported also by the Ninth Service Command, showing an incidence of osteomyelitis in 54 per cent of these wounds.

There can be no question that delayed primary closure of these compound fractures can be successfully accomplished in almost three out of four cases attempted and that, if it is successful, the incidence of osteomyelitis is sharply reduced. This is in addition to the other beneficial results enumerated above.

### TREATMENT OF LONG BONE FRACTURES

Long bone fractures were treated by skeletal traction, usually with Kirschner wire. An Army half-ring splint, with Pearson attachment, was utilized for balanced suspension. These long bone fractures were for the most part evacuated to fixed hospitals in the United Kingdom Base where the evacuation policy allowed a holding-period up to 120 days, whereas that period on the continent was 60 days maximum. It was our plan to hold these compound fractures in traction, following closure of the wounds until sufficient "freezing" or union had taken place, so that they would not displace when placed in circular plaster of paris splints for evacuation to the Zone of Interior. This holding-period varied from five to 12 weeks and even longer if necessary, depending upon the bone involved. Our principal error was in fractures of the shaft of the femur and trochanteric fractures which were not held in some instances sufficiently long prior to evacuation to the Zone of Interior, and displaced within the circular plaster splints with resulting malunion. Fortunately, this was quickly called to our attention and every effort was made to remedy this particular situation. Malunion in these badly damaged long bones all too often cannot be immediately avoided.

### HEALING OF COMPOUND FRACTURES

A report from 19 named General Hospitals on compound fractures due to wounds treated in the European Theater was received from the Surgeon-General at the request of the Chief Surgeon of the Theater. This report

was formulated during the month of December, 1944, so that the oldest cases reported were six months or less after being wounded. From the standpoint of union of the fractures, these 3,190 patients showed the following status of healing of their fractures:

2,189, or 68.6 per cent, were satisfactorily united.
417, or 13.3 per cent, were united in malposition.
2,606, or 81.9 per cent, —total united.
584, or 18 per cent, were ununited.

It was too early to consider all of the ununited fractures as nonunions. There was, however, a sizable group that due to the loss of bone by the original wounding agent, or to the overzealous removal of loose bone fragments by the inexperienced surgeon resulted in nonunion, requiring bone grafts to bridge the gap.

### AMPUTATIONS

The only amputation allowed in the Theater was the circular type which is considered an emergency measure. This amputation was done at the lowest possible level where a viable stump could be expected. It is really an inverted cone. The skin is divided in a circular manner and allowed to retract, the muscles are then divided at the level of the retracted skin, and they, in turn, retract still further and the bone or bones are divided transversely at the level of the retracted muscle. Traction is applied to the skin immediately and continued until the patient arrives at the Amputation Center in the Zone of Interior. If the amputation is performed for clostridial or other infection, skin traction is not applied for 24 to 48 hours, at which time it should be possible to determine whether the stump is infected or clean.

It was urgently insisted that continuous skin traction be maintained. This is best accomplished by weight and pulley over the foot of the bed while the patient is in the fixed hospital and by means of a plaster of paris pylon with a wire ladder splint incorporated while the patient is in transit. Stockinette fixed to the skin by Ace, or other adherent substance, and elastic cord or tubing were almost universally utilized. The amputee was usually advised that his amputation was necessary after consultation and that the procedure done in the Theater was an emergency measure which would require revision at the Amputation Center.

The amputations performed in the 3rd United States Army from August 1, 1944, to February 1, 1945, a six-months' period, were analyzed by Colonel Charles Odom, Surgical Consultant of that Army. There were 1,365 amputations performed upon 1,290 patients. Since 1,012 of these amputees were United States Army personnel among 64,389 battle casualties for that period of time, the incidence of amputation in this army was a little over 1.5 per cent of the wounded. Seventy-six per cent of the amputations occurred in the lower extremity, which is probably an indication of the efficacy of the land mines encountered. The causes of amputation were as follows: Traumatic amputation 66 per cent. Blood vessel injury 20.2 per cent. Clostridial infec-

tion 13.8 per cent. In the Army area the mortality among these 1,290 amputees was about nine per cent.

There are in World War II about 14,000 surviving major amputees among an estimated 8,000,000, or more, soldiers mobilized. In contrast to this, during the American Civil War, the Union and Confederate armies mobilized perhaps a total of three million men. There were 27,000 amputees in the Union Army and almost 25,000 among the Confederates, and the mortality in patients requiring this procedure at that time was approximately 25 per cent.

With the decrease in amputation as a means of treating the badly damaged extremity in battle casualties, there has been a corresponding increase in the compound fractures salvaged for treatment as outlined above.

### THE WOUNDED HAND

The serious nature of these wounds was appreciated early and efforts were made to expedite their evacuation to Hand Centers which were set up on the continent and in the United Kingdom. These damaged hands were often immobilized too long and too extensively, with resulting swelling and fibrosis. There was at times undue delay in transferring them to the Hand Centers where plastic and orthopedic surgeons were available to secure healing of the wound and early return of function. In an effort to avoid this prolonged rigid immobilization, the wounded hand was considered chiefly from the standpoint of its soft-parts. A pressure dressing, with the hand and fingers in functional position, was recommended, with elevation of the part and early closure of wounds by suture or skin graft—split-thickness or pedicle as required.

In March of 1945 we decided to try immediate loose primary closure of these wounded hands in all possible cases in the Army hospitals (Evacuation Hospitals for the most part). A careful and complete scrubbing of the wounded hand and a meticulous débridement were insisted upon prior to the immediate primary closure. The hand that had been sutured had to be held nonevacuable for five days. These regulations were put in effect in mid-April, 1945, and within a few weeks hostilities ceased. As an indication of what might be expected from this form of treatment, two surgeons in different Evacuation Hospitals reported immediate primary suture on a total of 80 hand wounds, with only five wound infections occurring. This was a vast improvement over delayed primary suture, and with early healing, rehabilitation of the wounded part could be commenced at an earlier period from the time of wounding.

Every effort was made to salvage one or two useful fingers in the severely damaged hands. No tendon replacement or bone grafts were undertaken in the Theater. Patients requiring this type of surgery were returned to the Zone of Interior. The prompt amputation of one or even two irretrievably damaged fingers with shattered bones and joints and severed flexor tendons will often afford the early salvage of an excellent three- or four-finger hand. With only one finger lost a soldier can be fairly promptly returned to full

duty. Early in the campaign a good deal of useless effort was expended in attempts to save one badly damaged finger—to the detriment of the hand.

*Wounds Involving Joints:* These wounds are always troublesome and potentially dangerous. Their proper treatment is based on sound basic surgical principles. Lt. Colonels Thompson and Cassebaum and Captain Stewart presented two important reports on the treatment of these joint wounds. The joint wound should be carefully explored through adequate incisions, all devitalized or damaged soft tissue and bone excised, all foreign bodies found in the joint cavity or overlying soft tissues should be removed and the joint gently lavaged. The capsule should be closed immediately by suture or fascial graft if necessary. The overlying soft-tissue wound is left open to be closed later by delayed primary closure. Twenty thousand units of penicillin are instilled into the closed joint cavity. Immobilization of the joint is secured by adequate and prescribed plaster of paris circular splint with a window for inspection of the joint should need arise. The patient with such a wound must be held nonevacuable for seven to ten days, during which time he receives parenteral penicillin, 20,000 units every three hours. If necessary, an additional 20,000 units of penicillin is injected into the joint cavity at 24-hour intervals. If healing proceeds uneventfully, the superficial wound is closed three to five days after primary surgery was done. By this treatment a high percentage of joint wounds were salvaged with useful motion.

In the irretrievably damaged joint or where infection is developing, an early resection of the joint will promote healing of the wound. In the joints of the lower extremity and wrist, fusion or arthrodesis is the goal to be sought, with the joint in the position to secure optimum function in the remaining mobile joints. In the elbow and shoulder joints after resection and healing of the wounds, early mobilization will give a surprisingly good range of motion with useful though by no means complete stability.

### COMBINED NEUROSURGICAL AND FRACTURE PROBLEMS

Approximately 75 per cent of the compound fractures complicated by nerve lesions occur in the upper extremity with the compound fracture of the humerus and injury to the radial nerve comprising the vast majority of these. The compound fracture of the femur with division of the sciatic nerve is fortunately not very frequently encountered, forming perhaps ten per cent of the total of these combined injuries. There is apparently no means of ascertaining in the first few weeks after wounding whether a nerve has been divided or merely badly contused. A high percentage of the nerves explored required only a neurolysis. The Senior Consultant in Neurosurgery, Colonel Glen Spurling, and the Senior Consultant in Orthopedic Surgery were in accord that the divided or potentially divided major peripheral nerve should be given precedence over the compound fracture.

The plan of treatment of these combined nerve and fracture problems was as follows: They were transferred immediately to a Neurosurgical Center. The wound was closed by delayed primary suture or skin graft. The fracture was meanwhile placed in balanced suspension. No effort was made to secure

anatomic length because this might defeat the attempt to get the nerve ends together. Three weeks after wound-healing had ensued, the nerve was explored and sutured if found divided. If it were necessary in order to get the nerve ends together, the bone was shortened up to 2.5 cm. This shortening was not frequently required. In the humerus it was of no moment, and in the few cases of the femur which required shortening, little or no disability due to the procedure was anticipated. These openly reduced fractures were treated by internal fixation. Needless to say, penicillin was quite extensively employed in these combined surgical procedures.

### OBSERVATIONS ON THE COMPARISON OF MEDICAL CARE OF THE WOUNDED IN WORLD WAR I AND WORLD WAR II

Having served as a medical officer in both wars, it may be permissible to make a few comparisons. The 25 years which elapsed between the wars has seen progress in the training of the young surgeons and this was reflected in the fact that more and better trained surgeons were available to do better surgery. There never were enough to completely fill all the existing vacancies. but the situation was vastly improved over World War I. In the European Theater the general level of care of bone and joint casualties was vastly improved. Superior care was unquestionably rendered by many of the affiliated hospitals in World War I, but in other less favored units it left much to be desired.

There was a more complete and general understanding of resuscitation in World War II. No blood or plasma was available or used in most of the Army hospitals in World War I. The great stocks of plasma and whole blood which were made available and were used so extensively saved many of the wounded who would otherwise have succumbed.

The evacuation of the wounded in World War II was more rapidly accomplished.

The overseas hospitals were very much better equipped for their work in this war.

The low incidence of infection was probably due to better surgery in the forward areas. In this matter of lower infection, the rôle of sulfonamides and penicillin is not absolutely clear. These new drugs probably exerted a beneficial effect, but controlled experimental data is not available.

The European Theater was singularly fortunate in having a Chief Surgeon whose sole aim was to improve the standard of care of the sick and wounded American soldier. Nothing deterred him from this aim. The professional service division had a group of consultants who worked harmoniously as a team under inspiring leadership of the Chief Surgeon and the Chief Consultants in Surgery and Medicine.

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# LAMINECTOMY FOR POTT'S PARAPLEGIA

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IT IS GENERALLY AGREED that about 90 per cent of all Pott's paraplegia patients will recover, given appropriate orthopedic care. The tendency in the past has been to consider the remaining 10 per cent hopeless.

Laminectomy has more often been withheld, than applied, in such cases, but the operation is finding a limited use. Seddon[1] reviewed a series of 25 laminectomies for Pott's paraplegia. With ten postoperative deaths, nine unimproved and six recoveries, he considered the results "appalling." Steindler,[2] however, in a group of 12 patients subjected to laminectomy, found seven relieved of their paraplegia. He believes the operation does have a limited use in the treatment of refractive cases of paraplegia.

The ill repute of laminectomy in Pott's paraplegia has come from the high mortality figures of the past, as many patients died from surgical shock. The operation at present, even in these often debilitated patients should carry no particular risk from shock. Laminectomy for spinal cord tumor or nucleus pulposus herniations, at present involves practically no risk from shock. Patients with Pott's paraplegia are by no means good risks, but death from shock after laminectomy should rarely occur.

Mechanically, laminectomy in Pott's disease has been strongly objected to because of the already diseased and weakened ventral elements of the spinal column. This objection cannot be held valid if fusion, either spontaneous or operative, has been achieved before the laminectomy is carried out, nor, considering the unfavorable nature of the group, can laminectomy be objected to in unfused patients, if spine fusion is performed at the time of the laminectomy.

A group of 23 consecutive cases, in which laminectomy was performed for Pott's paraplegia at the New York Orthopedic Hospital have been reviewed. These patients were considered by the staff to be among the 10 per cent generally considered hopeless. The paraplegia, which was usually severe, had failed to respond to the usual orthopedic measures. Fifteen of these patients showed a spinal manometric block with an elevated protein. Six had a high protein but no manometric block. One had a normal manometric test with a normal protein. Lumbar puncture was not carried out in one case.

Fifteen of the patients had had surgical fusion, and one had developed spontaneous fusion, before a laminectomy was decided upon. In the remaining seven unfused cases, spine fusion was carried out at the time of the laminectomy.

Disregarding, for the moment, such modifying factors as age, and the type of intraspinal lesion found, the results were as follows: Eight patients had a good result. They were walking well when last heard from. Three

patients were improved. They could walk with various degrees of difficulty. Ten were unimproved by operation. The follow-up period varied from a few months in a few, to as much as 11 years in others. There were two deaths, but neither of these was from surgical shock. A child died four weeks after laminectomy from tuberculous meningitis. It is possible that this condition was beginning, though unrecognized, at the time of operation. An adult negro died 33 days after laminectomy. Necropsy showed very wide spread, long-standing tuberculosis of many viscera. It is difficult to classify this as a postoperative death, in the usual meaning of the term.

In deciding whether these results be good, bad or indifferent, it seems fair to repeat that this group represents the 10 per cent of Pott's paraplegia, generally considered to be hopeless. It is not unreasonable to believe that any result better than hopeless is a step in the right direction.

Of the 15 adults, three obtained a good result, whereas, of eight children operated upon, five had good results. The figures from this group suggest that laminectomy for Pott's paraplegia is more hopeful in children.

The intraspinal lesions found at operation were the three well-recognized conditions described in the literature. Eight patients had a thick, localized mass of granulations surrounding the dura. Eight had, as far as could be determined, compression of the cord ventrally by the diseased vertebral bodies. Seven patients proved to have an intraspinal, extradural cold abscess. The good results showed no relation to the type of intraspinal pathology—three, having granulations, three, compression of the cord ventrally by bone, and two, having cold abscesses.

Of the eight good results, six were obtained in patients with an early onset type of paraplegia (paralysis developing in the first two years of the disease). Two good results were obtained in the late onset type of paraplegia. However, of the total of 23 cases, 14 were of the early onset-type of paraplegia. No relationship between the type of paraplegia and the result from laminectomy can be shown from these figures.

The location for the laminectomy was, in every instance, determined by the sensory level present. Actually, in all cases, the sensory level, the intraspinal pathology and the apex of the kyphos all corresponded very closely.

There is little to be said about the technical aspects of the laminectomy except to stress the fact that it was made for decompression only. The cold abscesses were aspirated, as far as possible, but the other two types of lesions were strictly undisturbed. The laminectomy in every case was made rather longer and narrower than would ordinarily be made for other neurosurgical problems. This was in respect to the already existing fusion in some, or to permit satisfactory fusion when carried out at the time of the laminectomy. The dura was never opened because of the presence of tuberculosis.

A group of 23 patients with refractive Pott's paraplegia received a decompressive laminectomy. The results are briefly stated for record purposes, rather than as an argument for, or against, the operation. The neurologic surgeon sees little of the problems of tuberculosis, but given a patient with

refractive Pott's paraplegia, particularly if a spinal manometric block be present, it seems difficult to withhold a decompressive laminectomy.

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# INDICATIONS AND RESULTS OF SURGERY OF THE AUTONOMIC NERVOUS SYSTEM IN NAVAL PERSONNEL*

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The indications for surgery of the sympathetic nervous system in Naval personnel, arranged in order of their relative importance, have been:

A. Causalgia of the classical "Weir Mitchell" type.
B. Pain after amputation.
C. Peripheral vascular disease.
   1. Raynaud's syndrome.
   2. Thrombo-angiitis obliterans.
   3. Vasospasm with arteriosclerosis.
   4. Thrombophlebitic complications with vasospasm.
   5. Vasospasm following injury to major arteries.
D. Hyperhidrosis.
E. Hypertension.
F. Angina pectoris.

The methods of study have been recorded individually. Operative procedures used by this group have been those formulated by Capt. J. C. White and Reginald Smithwick.[18] Completeness of preganglionic sympathectomy has been measured by elevated cutaneous resistance changes, (measured by Richter's[15] dermometer), by paralysis of the sweat glands (determined by Victor Minor's[12] starch-iodine test), and by objective signs of an asymptomatic hot, dry, extremity.

## A. CAUSALGIA

*Methods of Study.*—We have included in this group only those cases which conform to the picture of major causalgia described by Mitchell, Morehouse, and Keen,[13] and we quote excerpts of their classical description:

"Recently we have seen numbers of men who had burning pain without glossy skin, and in some we have seen this latter condition commencing. The burning comes first, the skin change afterward; but in no case of great depravity in the nutrient condition of the skin have we failed to meet with it, and that in its forms of almost unendurable anguish. The terms here used may seem strong to those who have not encountered these cases; but no one who has seen them will think that, as regards some of them, it would be possible to overstate their most wretched condition. The seat of burning pain is very various; but it never attacks the trunk, rarely the arm or thigh, and not often

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the forearm or leg. Its favorite site is the foot or hand. In these parts it is to be found most often where the nutritive skin changes are met with; that is to say, on the palm of the hand, or palmar face of the fingers, and on the dorsum of the foot: scarcely ever on the sole of the foot or the back of the hand. The part itself is not alone subject to an intense burning sensation, but becomes exquisitely hyperaesthetic, so that a touch or a tap of the finger increases the pain. Exposure to the air is avoided by the patient with a care which seems absurd, and most of the bad cases keep the hand constantly wet, finding relief in the moisture rather than in the coolness of the application. Two of these sufferers carried a bottle of water and a sponge, and never permitted the part to become dry for a moment. As the pain increases, the general sympathy becomes more marked. The temper changes and grows irritable, the face becomes anxious, and has a look of weariness and suffering. The sleep is restless, and the constitutional condition, reacting on the wounded limb, exasperates the hyperaesthetic state, so that the rattling of a newspaper, a breath of air, another's step across the ward, the vibrations caused by a military band, or the shock of the feet in walking, give rise to increase of pain. We feel that we may be supposed to have exaggerated somewhat in delineating these hitherto undescribed neural disorders. Surgeons who have happened to encounter a single one of the worst of them, have been so surprised at the character of the suffering as to suspect that such extreme hyperaesthesia must be due, at least in some measure, to a desire on the part of the patient to magnify his pains. If we be not mistaken, this form of neuralgia is hitherto undescribed. Perhaps no pen can do it justice without the more life-like details of cases."

In classical causalgia, the condition of the patient precludes practical quantitative methods of evaluating symptoms. In Table I, the symptoms of this group are noted. If these symptoms have been relieved by paravertebral procaine block, preganglionic sympathectomy has been performed with consistently successful results. A classical case is cited in detail:

**Case Report.**—Charles C., Pvt., U.S.M.C.R.—Age 21: The patient was injured on Okinawa by a booby-trap explosion. Fragments of the bomb entered the forehead, right thigh and left arm without serious injury or loss of consciousness. He was evacuated to the rear and four hours after injury he developed marked burning pain in the left forearm and hand with evidence of incomplete injury to the median nerve. On June 18, 1945, the median nerve of the left arm was explored and neurolysis performed, without alleviating causalgic symptoms. The patient continued in extreme constant distress. This consisted of diffuse burning pain in the left forearm and hand, made worse by any type of emotional disturbance, such as radio, movies, loud talking, *etc.*, and also by exposure to cold. The patient could not be kept in an open ward, but required a quiet room where he constantly either soaked his hand in warm water or wrapped it in wet towels. He was unable to use the extremity because of the extreme hyperpathia. On July 14, 1945, a paravertebral procaine block of ganglia T2 and T3 resulted in complete temporary relief from symptoms. A thoracic preganglionic sympathectomy was performed three days later, with immediate and complete relief of causalgia. Ten days after operation, the patient was playing volley ball.

*Discussion on Causalgia.*—There are various theories as to the etiology of causalgia. Our cases favor the theory of Doupe, Cullen and Chance,[4] who state: "The qualities of causalgic pain are due to direct cross-stimulation of sensory fibers by afferent sympathetic impulses at the point where the nerve trunk is injured." This theory provides an explanation for the severe hyper-

pathia which occurs in cold environment, as a result of excitement or cutaneous stimulation, and, as demonstrated by some of our cases, by defecation, micturition (Case 1), and swallowing cold liquids (Case 5). Experimentally, Katz and Schmidt[8] have corroborated the theory of sympathetic activation of sensory fibers by demonstrating that, under specified conditions, efferent nerve impulses can alter the excitability of adjacent sensory axones. Direct experimental proof of cross-stimulation between motor and sensory fibers at point of nerve injury has been demonstrated by Granite, Legksell, and Skoglumd.[5] These workers, with the aid of the cathode ray oscillograph have recorded the afferent discharge from a sensory root which occurs when an injured motor root is stimulated.

Our patients in this group presented evidence of overactivity of the sympathetic nervous system. Their hyperpathia was made worse by lowering of environmental temperature, by increased emotional excitement induced by noise, exciting movies, and noisy radios. One patient suffered severe hyperpathia from micturition and another from drinking cold water. If operation is to be successful in this group of patients, preganglionic sypmathectomy must be complete.

In case, for example, the removal of two distinct ganglia at the side of the 2nd lumbar vertebra only relieved the burning hyperesthesia in the proximal two thirds of the foot. Vestiges of sweat secretion and a suspiciously low electrical skin resistance induced us to try procaine block at the level of the 3rd and 4th lumbar vertebrae. This abolished all residual pain in the toes, and the effect was thought to have been made permanent by removing an anomalous lower ganglion at the side of the 3rd vertebra. However, the patient soon began to complain of pain and burning in the ball of the foot. This was completely relieved by procaine block of the posterior tibial nerve. Neurolysis revealed a slight scar about this nerve, and the patient is now symptom-free. Relief by this procedure again suggests anomalous sympathetic fibers.

### B. PAIN AFTER AMPUTATION

#### *Other than Local Tenderness of a Neuroma*

*Methods of Study.*—The methods were essentially the same as those listed for the causalgia group, and have been directed to evaluate the rôle of the sympathetic system. Whenever relief of pain was obtained after paravertebral procaine block, the patient was subjected to preganglionic sympathectomy. The data of such patients is found in Table II.

All these patients had had peripheral amputations, mostly of the fingers or toes. It is, of course, in this region that the release of vasoconstrictor tone after sympathectomy is most pronounced. Furthermore, all the cases in this group presented evidence of increased vasomotor phenomena and the patients had cold, sweaty extremities. Their pain was aggravated by lowered environmental temperature, but not by emotional stimuli. The character of this type of pain after peripheral amputation has consisted of a deep aching with a diffuse hyperthesia at times involving a whole limb. It was not similar to the

burning hyperpathia of major causalgia. Symptoms complained of by the patients summarized in Table II are quite different from those seen with a mechanically irritated neuroma, phantom limb, or the episode of lancinating pain or bursting pain occasionally encountered in the major amputation neuralgias. These conditions have recently been discussed by one of us,[19] and require an altogether different form of treatment.

TABLE II

RELIEF OF LOCAL PAIN AFTER AMPUTATION BY INTERRUPTION OF SYMPATHETIC FIBERS

| Case | Condition | Surgical Procedures | Relief |
|---|---|---|---|
| 14. Henry J. CM3c USN | Traumatic amputation of distal phalanges of 4th and 5th fingers. Very cold, cyanotic, sweaty hands | (1) Paravertebral procaine block. T1—T2<br>(2) Upper thoracic preganglionic sympathectomy | Temp. relief. Warm hand and arm free of former deep pain at discharge. (3 weeks) |
| 15. John G. S3c USN | Traumatic amputation 2nd and 3rd fingers. Local hyperesthesia in 3rd finger had been relieved by excision of neuroma, but without effect on neuralgia of hand and forearm | (1) Paravertebral procaine block. T1—T2<br>(2) Upper thoracic preganglionic sympathectomy | Temp. relief. Complete relief of ascending neuralgic pain. Pt. still complained of hypersensitive index finger, but was able to return to limited duty |
| 16. Philip C. Sgt. USMC | Traumatic amputation tip of 5th finger with repeated amputations to metacarpal level for local hyperesthesia and deep ache in hand and arm. Cold, cyanotic hands | (1) Procaine block of upper thoracic ganglia<br>(2) Upper thoracic preganglionic sympathectomy | Relief for 2 hours. Nearly complete relief of deep aching pain in hand and arm at 3 months |
| 17. Henry C. S2c USNR | Traumatic amputation 3rd toe with severe pain in stump and bottom of foot. Aggravated by cold, not by psychic stimuli | (1) Paravertebral procaine block, L2—L4<br>(2) Lumbar sympathectomy, L2—L3 | Temporary relief<br>Complete relief at 2 months |
| 18. James L. A.S. RN | Traumatic metatarsal amput. with pain in stump running up to knee. Deep ache in left foot. Deep ache worse in cold weather. All 4 extremities involved in vasospasm. Left foot cold and sweaty | (1) Procaine paravert. L. block<br>(2) Lumbar sympathectomy L-1-2-3 | (1) Foot hot and dry, pt. comfortable<br>(2) Complete relief of symptoms, return to orthopedic service for repair of stump |
| 19. Henry C. S2c USNR Age 24 | Traumatic amputation 3rd right toe with pain in stump which continued after revision of stump. Foot cold and cyanotic. Hyperesthesia over lower ½ foot | (1) Procaine symp. block, L-2-3<br>(2) Lumbar sympathectomy L-1-2-3 | (1) Pain disappeared with complete vasodilatation<br>(2) Complete relief of symptoms |

### C. PERIPHERAL VASCULAR DISEASE

*Methods of Study.*—These patients were first studied on the Medical Service, and when it was apparent that the problem was one of peripheral vascular symptomatology, the following methods were used for detailed investigation:

The extremities in question were observed for color and rapidity of change in color resultant from changes in position; for differences in temperature; absence of peripheral pulses; oscillometric readings; degree of sweating; and presence or absence of arterial calcification roentgenologically. Changes in temperature and color of the digits and extremities before and after procaine block of the sympathetic efferent fibers either by paravertebral injection of procaine, spinal anesthesia, or peripheral nerve block were recorded in a room of nearly constant temperature.

It should be added, parenthetically, that in thrombo-angiitis obliterans an

increase in collateral circulation and reduction of intermittent claudication will often follow preganglionic sympathectomy, even though no striking improvement can be demonstrated during the brief period of vasoconstrictor paralysis which follows procaine block. As stated by White and Smithwick,[18] sympathectomy is generally worth a routine trial in younger individuals who have not lost their femoral pulse and do not have infection or painful gangrene.

*Discussion of Peripheral Vascular Group.*—This group of patients with peripheral vascular disease, which falls into a number of categories, all have well-defined vasospastic phenomena, in common.

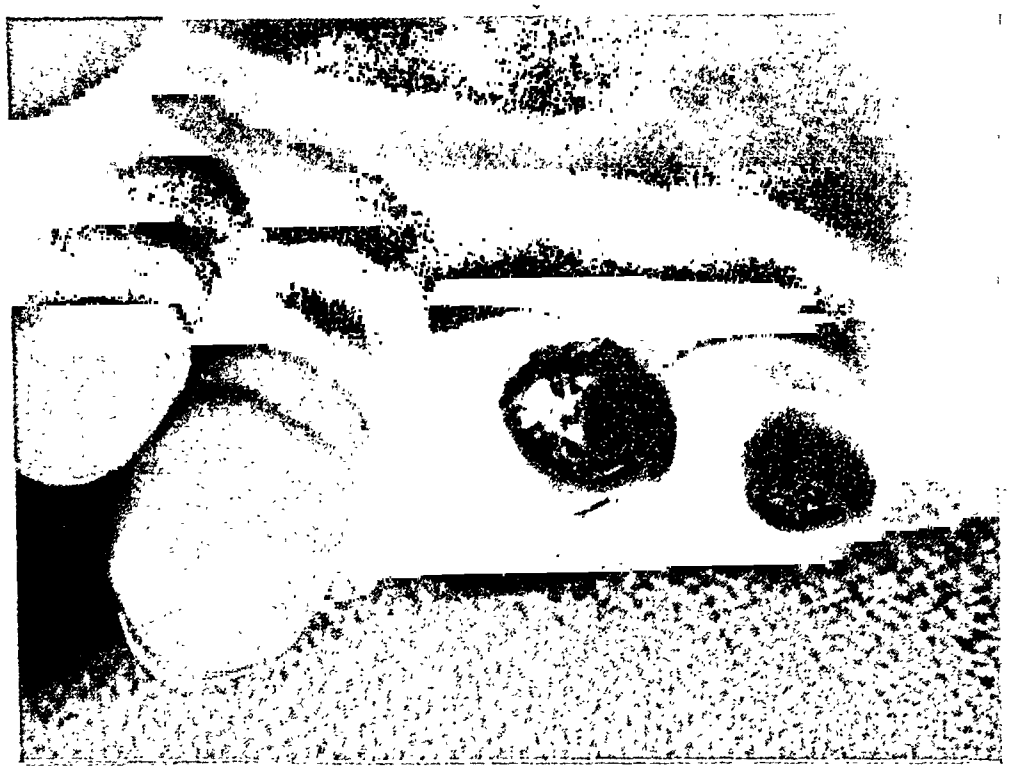
1. *The Raynaud's Syndrome:* This group of patients have vasopastic disorders with color changes, but not necessarily advanced to the stage of dead-white fingers. As Lewis first pointed out, when the disease has advanced to the stage of pallid asphyxia of the fingers during exposure to cold, this phenomenon is not caused by extreme vasoconstriction, but by local changes in the walls of the digital arteries. The few biopsies which have been secured have all shown the presence of a true endarteritis obliterans.[18] The complication of a dead-white finger and also the association of scleroderma will minimize the good results that otherwise might be obtained from preganglionic sympathectomy. It should be recognized that the Raynaud's phenomena may cover a wide range of vasomotor and sudomotor disturbances, from the cold, wet, cyanotic hands, in which there are no endarteritic changes (Plate IA), to the cold, white, dry hand resembling that seen in advanced occlusive vascular disease. In the former, preganglionic sympathectomy gives uniformly gratifying results, but naturally when endarteritic changes have occurred, the results are less satisfactory. Therefore, emphasis must be placed on early diagnosis and operation. The applicability of these facts is well demonstrated in our cases (See Table III). We are aware of the criteria of Allen and Brown,[1] recently reëmphasized by Hines and Christensen,[6] for the accurate diagnosis of Raynaud's disease in men. However, we are of the opinion that if one waits for the Raynaud's phenomena to progress to the so-called Raynaud's disease, the most opportune time for operation will have been lost.

2. *Thrombo-angiitis Obliterans:* In this group, it is our opinion that optimum results are obtained in those patients who have no sepsis or gangrene, and who have femoral pulsations. If recognized early, preganglionic sympathectomy will afford immediate satisfactory results. In this group, studied at the Massachusetts General Hospital, the incidence of amputation has been reduced from 50 per cent to 10 per cent.[18] Pain in thrombo-angiitis obliterans associated with sepsis or gangrene is best treated by preliminary peripheral nerve crush, which gives in effect a temporary sympathectomy.[17] When this procedure is followed by healing of the ulcer with general improvement of the extremity, pregangionic sympathectomy is indicated.

In our group, there have been instances of impending gangrene in which restoration of adequate circulation through preganglionic sympathectomy resulted in prompt healing (Plate IB). It is striking to observe the complete relief of painful symptoms and the rapidity of tissue restoration in these indi-

PLATE I

A



Thrombo-angiitis obliterans (Case 31).
A. Status of fingers on day before sympathectomy.



B

B. Appearance of fingers ten days after R. thoracic sympathectomy. Only slight discoloration of 4th and 5th R. finger tips is visible and gangrenous ulcers are completely healed.

viduals (Fig. 2) in contrast to the results of lengthly treatments other than sympathectomy. There have been no amputations in our small series. We are not in agreement with Montgomery,[14] who states that sympathectomy is of no use when the vessels are no longer capable of dilation, for our cases demonstrate that if only the femoral arteries are patent, preganglionic sympathectomy is good prophylaxis in protecting the new collateral vessels from vasoconstricting influences. While our cases have not had the benefit of lengthly follow-up, it is evident that they have been physically and economically rehabilitated within a few weeks and none have suffered amputations. It should be noted that all these patients have been advised to cease the use of tobacco in any form and to use alcohol in therapeutic doses. An interesting case history is quoted in detail:

**Case Report.**—Joseph L. Momm 2c, U.S.N.R.: Thrombo-angiitis obliterans.

In May, 1944, this 36-year-old white male complained of soreness of right knee followed by cold and painful right big toe. In turn there followed painful right instep and ankle aggravated by hikes. In July, 1944, patient complained of cramp-like sensation in right ankle followed by right palmar pain. By November, 1944, he began to shirk work due to a painful right ankle and he noted discoloration and coolness of right midleg region. A few weeks later patient was hospitalized and treated for thrombo-phlebitis of right leg. In April, 1945, the 4th and 5th fingers of right hand were noted to be cold and painful and a month later ulceration of nail bed of 5th right finger was noted. One week later, tip of 4th finger ulcerated. Patient was treated for fungus infection of finger tips and returned to U. S. for demobilization. At Separation Center he complained of claudication of legs and extremely painful discolored ulcerated 4th and 5th fingers of right hand which patient described as "stone cold." Pertinent physical findings on admission to this hospital were classical signs of thrombo-angiitis obliterans of all four extremities, with ulcerations of 4th and 5th right fingers. Right thoracic procaine paravertebral block gave immediate relief of symptoms and a warm, dry hand. Following preganglionic thoracic sympathectomy, immediate relief of symptoms was obtained and healing of the ulcerations of the 4th and 5th right fingers was complete by 4th postoperative day. At suitable intervals, right and left lumbar sympathectomies were done on this patient with good results, and he no longer had claudication in his legs.

3. *Arteriosclerosis with Vasospasm:* Preganglionic sympathectomy can only be expected to give satisfactory results in this group if there is evidence of excessive sympathetic tone. If the extremity is cold and moist and there is a fair response to a temporary block of the sympathetic outflow, preganglionic sympathectomy offers a reasonable chance of increasing the effective circulation of the extremity. Case 32 represents a satisfactory response to this operation.

4. *Thrombophlebitic Complications with Vasospasm:* These cases were instances of thrombophlebitis in which, after the acute process had subsided, there remained edema, pain, and evidence of vasospasm. They presented cold, sweaty extremities which became warm, dry and painless after sympathetic block.

5. *Vasospasm Following Wounds of Major Arteries:* Numerous reports have appeared in the past year dealing with wounds of major vessels.[2, 3, 16] In

a personal communication to one of us (J. C. W.), Brigadier Ogilvie* stated that he had seen no successful cases of popliteal ligation in the African Desert campaign, without added sympathectomy.

One of our patients (James W., age 27, Slc) suffered injury and severance of his left popliteal artery by shrapnel. Following ligation he had a cool left leg and foot, claudication of calf muscles, and hyperhydrosis of the foot. All symptoms were relieved by procaine block of L1,2.3. After lumbar sympathectomy, the foot was warm, pink, and dry, the pedal pulse increased in volume, and he complained only of slight calf ache on walking.

### D. HYPERHYDROSIS

Both of our cases obtained satisfactory relief from preganglionic sympathectomy (Table IV). Hyperhydrosis is most common in young, emotional people in whom there is usually circumstantial evidence of a psychosomatic

TABLE IV

HYPERHIDROSIS

| Pt. | Presenting Symptoms | Duration of Symptoms | Pertinent Findings | Operation | Result of Operation |
|---|---|---|---|---|---|
| 36. Thoreau W. Pfc. Age 26 | Excessive sweating feet with cold blue feet in cold weather. Had filiarisis | 1 mo. | Cold hyperhidrotic feet, cyanosis feet. Pulsations intact. Chr. dermophytosis feet | Right lumbar sympathectomy | Hot dry right foot. Back on guard duty 3 mos. |
| 37. Larson P. RM3c Age 25 | Hyperhidrosis of hands with maceration palms | yrs. | Extreme hyperhidrosis. Feet to lesser degree | Bilat. thoracic preganglionic sympathectomy | Warm, dry hands. 4 mos. |

disorder. The symptoms have been most incapacitating in stenographers and medical students, and those handling delicate fabrics. Although these people are not suitable for the armed forces, they can be rehabilitated for civilian occupations by preganglionic sympathectomy.

### E. HYPERTENSION

*Methods of Study.*—The persistence and range of abnormally elevated blood pressures in our patients was observed over a sufficient period of time to rule out anxiety states, combat fatigue, metabolic disturbances and hypertension of known endocrine origin. Methods used for evaluation of renal function were the P. S. P., urea clearance, concentration tests and frequent examinations of the urine. Intravenous pyelogram studies ruled out gross structural kidney changes and retrograde pyelography and perirenal air insufflation studies were used as supplementary procedures when indicated. Range of alteration of blood pressure, as a measure of the reactivity of the sympathetic nervous system, was measured by the use of the cold pressor test of Hines,[7] the sodium amytal sedation test, and in some of our patients by the standardized "two-step test" of Masters.[10, 11] Examination of the fundi was carried out by a competent ophthalmologist and the findings graded according

* British consultant to Montgomery's Army.

to the classification of Keith, *et al.*[9] The results of radical thoracolumbar sympathectomy in 14 patients are summarized in Table V. Two interesting case histories are cited in detail:

**Case 1.**—Robert R., age 35, Lt., U. S. N. R. (Case 51). Hypertension.

For six months prior to admission to the hospital in 1945, the patient began to notice easy fatigability followed by headaches of three months' duration and blurring of vision and nocturia of one month duration. Ten days prior to admission he had suffered a series of convulsions, amnesia, and fell out of bed, injuring his forehead. Familial history revealed that his father was suffering from angina pectoris and occlusive vascular disease, with the loss of a lower extremity.

*Physical Examination.*—The fundi showed papilledema and blurred disk margins; old "cotton wool" hemorrhages were seen and some scars of old hemorrhages. The fundi were classed as Grade III. The heart was judged to be normal and roentgenograms revealed no increase in size. The E. C. G. was thought to be significant of coronary disease. Neurologic examination was normal. The urine contained 1+ albumen and concentrated to a sp. gr. of 1.021. N.P.N. was 34.5 mg. per cent. I.V.P. was normal. Events are now best noted in chronologic order.

5-19-45: Convulsions. Intraspinal pressure 390 mm. $H_2O$.

5-21-45: B/P.— Lying 200/130 Sitting 190/140 Standing 200/150

6-4-45: Convulsion yesterday and this A.M.

6-7-45: Right thoracic lumbar sympathectomy—kidney and adrenal palpated and found to be normal.

6-15-45: Complains of more blurring of vision. Has vertigo, faintness and headache which makes it impossible to get him up.

P.S.P. 55° N.P.N. 40 Urine sp. gr. 1.015

6-16-45: B/P. 200/120

6-22-45: Left thoracolumbar sympathectomy. Renal biopsy. B. P. 70/40 after operation.

6-24-45: B/P. 180/120 to 150/110. Fundi show great many more recent hemorrhages-exudate.

7-1-45: B/P. 150/90 to 160/100. Patient noting subjective eye improvement.

7-2-45: Up walking—no orthostatic failure.

7-8-45: B/P. — Lying 146/90 Sitting 136/90 Standing. 130/80 Intraspinal pressure 220 mm. $H_2O$.

7-31-45: Remarkable improvement

8-14-45: B/P. Sitting 155/110 to 145/110 Standing 145–135/100 Smoking 2 cigarettes 155/120

Feels well—swims—skips rope.

12-21-45: B/P. Sitting 160/120 Walking 3 flights of stairs 170/120 to 160/120

Disks have nearly returned to normal. Vision good, still tires easily, occasional headaches, no orthostatic hypotension.

1-7-46: B/P. 180/120 to 160/110, no difference in positions.

Told interesting story of how prior to his cerebral crisis, he had worked out an important device for the Navy in connection with radar electronics. He had entirely lost track of his work after the cerebral crisis. Since returning to his desk after operation, he was able to pick up the threads of the idea again.

2-8-44: B/P. 170/100.

8-1-44: Working hard at M.I.T. for Navy — tires easily — B/P. 160/130.

11-27-44: Readmitted — B/P. *168/118 to 196/128.* Heart not enlarged—A2 greater than P2, normal rate and rhythm. N.P.N. 36, Urine Alb. 0, Casts 0, sp. gr. 1.020. Fundi normal, except for narrowed vessels with nicking.

TABLE V

HYPERTENSION

| Name | Duration of Symptoms | Pertinent Findings | Operation | Result of Operation |
|---|---|---|---|---|
| 38. Ruth D. Age 31 | 6 yrs. | Easy fatigibility, headaches, irritability, florid face. Grade II eyegrounds. Cardiovascular system *normal. Renal function good.* Heart not enlarged. ECG L. ventricular strain. 240 190 BP —— — ——. 130 130 Good sedation test | Bilat. thoracolumbar sympathectomy. T10— *L2* | Improvement in eyegrounds; less irritable and nervous. *140* *160* BP —— — ——. 88 96 |
| 39. Francis H. VAP Age 44 | 1 yr. | EP 200 irritable. Eyegrounds grounds Grade II. Cardiovascular system normal. Renal function good. Heart not enlarged by roentgen-ray. Had 2 hypertensive cerebral crises 3 wks. before op. | Bilat. thoracolumbar sympathectomy. T10—L1, R. T9 —L1, L. | 140 160 BP —— — ——. 3½ 90 100 mos. Returned to work as shipping clerk |
| 40. Margaret H. Age 31 | 4 yrs. | Severe headaches and precordial pain relieved by rest. Irritable with occ. blurring of vision. Normal C-V system. Heart not enlarged. ECG normal. Fundi Grade I. 175 BP ——. Abnormal cold pressor 100 test | Bilat. thoracolumbar sympathectomy. T10—L3, R. T10—L2, L. | 118 132 BP —— — ——. 76 80 Emotionally stable 14 mos. General sense of well-being. Renal biopsy—chr. vascular nephritis Grade III |
| 41. James G. VAP Age 47 | | Cerebrobvascular crises. 140 190 BP —— — ——. 98 120 Eyegrounds Grade II | Bilat. thoracolumbar sympathectomy. T9—L1, R. T9—L2, L. | 125 140 —— — ——. *6 mos.* 100 110 General sense well-being. Renal biopsy, chr. vascular nephritis Grade III |
| 42. Anna G. Age 47 | 6 yrs. | Severe headaches, vertigo, easy fatigability. Eyegrounds Grade II. 220 BP ——. ECG normal. Renal 130 Renal function tests good. Chest normal | Bilat. thoracolumbar sympathectomy. T10—L2 | 180 BP ——. 10 mos. less 100 nervous and irritable. Returned to light work. |
| 43. Thomas B. Age 55 | 3 yrs. | Nervousness, headaches, irritability, tinnitus, vertigo of 3 wks. duration. Eye grounds Grade II. *188* *206* BP —— — ——. Cardiovascular 108 116 *system normal.* Sclerosis and tortuosity aorta by roentgen-ray. Renal function good. ECG normal | Bilat. thoracolumbar sympathectomy. T9—L2, R. T8—*L2*, L. | Returned to active Naval duty—6 mos. 150 BP ——. *Doing light* 100 duty 11 mos., no further reduction in BP. |
| 44. Lillian I. (Mrs.) Age 34 | 2 yrs. | Nervousness, vertigo, headaches, blurring vision. 168 210 BP —— — ——. Eyegrounds, 110 140 Grade II. Normal cardiovascular system and ECG. Slight impairment renal function. 3 mos. pregnant with past history of several miscarriages | Bilat. thoracolumbar sympathectomy. T8—L2, R. T9—L2, L. | Operation done during early mos. of pregnancy. Stroke during 7th mo. of pregnancy but with excellent recovery. Normal baby. Throughout pregnancy *130* BP ——, but thereafter 90 180 it rose to ——. 100 |
| 45. Helen M. (Mrs.) Age 41 | 10 yrs. | 5 stillborn children. Eyegrounds Grade II. Nervous. 215 240 BP —— — ——. 112 140 Heart slightly enlarged with systolic murmur at apex. ECG shows cardiac changes, compatiable with hypertension. Renal function aver. | Bilat. thoracolumbar sympathectomy. T9—L3, R. T6—L2, L. | Striking postural hypotension. At 9 mos. back to work. 160 100 BP —— — —— 100 80 Has residual symptoms |

TABLE V—Continued

| Name | Duration of Symptoms | Pertinent Findings | Operation | Result of Operation |
|---|---|---|---|---|
| 46. Edward H. Lt. USNR Age 28 | 7 yrs. | Dyspnea, headaches, precordial pain on exertion, of 6 mos. duration. BP 160/110. Eyegrounds Grade I. Cardiovascular system normal. 2-step test positive. Urinary functions good. Positive cold pressor test | Bilat. thoracolumbar sympathectomy. T8—L1 | Excellent. BP 118/80 — 130/90. Cold pressor test no longer positive. 2-step test not positive. Emotionally stable. No further precordial pain. 3 mos. |
| 47. Charles C. W/O USN Age 41 | 2½ yrs. | BP 150/105 — 2 mos. morning headache and dyspnea on exertion. Eyegrounds Grade II. Heart slightly enlarged with fullness L. ventricle by roentgen-ray. ECG compatiable with hypertension. Renal function good. Abnormal cold pressor test | Bilat. thoracolumbar sympathectomy T8—L2. | BP 130/90 — 140/98. Relieved of all symptoms. 2 mos. |
| 48. Joseph F. MM3c Age 22 | 4 mos. | Severe frontal headaches. BP 160/110 — 180/120. Eyegrounds within normal limits. Cardiovascular system normal. Renal function good. ECG within normal limits. Abnormal cold pressor test. Good sedation test | Bilat. thoracolumbar sympathectomy T8—L2. | BP 110/82 — 120/88. Relieved of all symptoms. 2 mos. |
| 49. Barclay W. Lt. USN Age 27 | 4 mos. | Severe occipital headaches. Fundi Grade II. Cardiovascular workup neg. ECG, L. axis deviation. Blood chem. normal. Urinary function good. Abnormal cold pressor test. BP 150/100 — 180/130 | Bilat. thoracolumbar sympathectomy. T10—L1 | Free from headaches. Feels well. BP 130/100 — 1 yr. later. Returned to duty in Pay Corps, but BP 160/110 — 185/130 — 2 yrs. later. Kidney biopsy showed Grade II hypertensive changes |
| 50. William W. VAP Age 45 | 13 mos. | Residual signs of R. hemiplegia and recent L. hemiplegia. Heart enlarged, tortuous aorta by roentgen-ray. ECG abnormal. Urine alb., diminished ability to concentrate. Fundi Grade III. I-V pyelogram normal. BP 220/130 — 300/140 Bilat. Hoffman PSP 20% excretion | Bilat. thoracolumbar sympathectomy. T9—L2. | BP Lying 200/130 — Sitting 170/120. Standing 80—dizzy — 0—faint No late follow-up. Biopsy kidney chr. vascular nephritis, Grade I |
| 51. Robert R. Lt. USNR Age 35 | 6 mos. | 6 mos. fatigue, headaches. 3 mos. visual blurring and nocturia 1 mo. Eyegrounds Grade IV. Convulsions with amnesia 1 mo. Normal pyelogram. Urine-alb.-diminished concentration power. ECG—coronary disease. Lumbar puncture inc. pressure without increased protein. BP 190/130 — 200/150. Markedly abnormal cold pressor test | Bilat. thoracolumbar sympathectomy. T8—L3. | Improvement in eyegrounds. Decreased CSF* pressure. BP 125/90 — 118/100. 14 mos. Fundi almost normal 2-step test indicative of coronary insufficiency |

* Cerebrospinal fluid.

| 12-4-44: B/P. | Lying | Sitting | Standing | Ice water | Lying | Standing |
|---|---|---|---|---|---|---|
| | 198/120 | 194/128 | 200/138 | | 200/122–190/114 | 196/128 |
| Pulse | 96 | 88 | 100 | | 88 | 96 |

Eyegrounds clear of exudate, hemorrhages or papilledema; moderate nicking.

12-5-44: Old incision reopened and carried up to rib 7. L2 and L3 ganglia removed. R10 then resected (5 cm.) T8, T9, T10 ganglia and 5 cm. of major splanchnic nerve resected. B/P. 130/80.

12-7-44: B/P. 190/110.

12-13-44: B/P. at former level

1-4-45: B/P. back to old level.

| 2-1-45: Well — B/P. | Lying | Sitting | Standing |
|---|---|---|---|
| | 160/110 | 155/105 | 160/100 |

9-5-45: Reëxamination at U. S. N. H. St. Albans. Doing six hours work, six days a week at M. I. T.

| B/P. | Lying | Sitting | Standing |
|---|---|---|---|
| | 165/110 | 166/118 | 166/120 |

Fundi almost normal, minimal A-V nicking. Arteries slightly narrowed. Veins normal. Disk normal. No exudates or hemorrhages.

Cold pressor test — 154/120 to 160/115

Pulse 76 72

in striking contrast to previous test of 5-31-43 which was 200/140 to 300+/180.

**Case 2.**—Edward H., Lt. (jg) U.S.N.R. (Case 46).

This 29-year-old officer was known to have mild hypertension at the age of 22. When he started naval service in 1942, his B.P. was recorded as 148/98. In 1943, he was hospitalized for the complaint of precordial pain and his B.P. at that time was recorded as 176/100, falling to the level of 128/80 with bed rest. He was then returned to duty. When examined for promotion in June, 1945, it was ascertained that his B.P. was 170/112. At this examination, he complained of frequent headaches, mild dyspnea, irritability, and precordial pain with exertion. He was, therefore, hospitalized for further investigation. No familial history of hypertension was obtained.

Pertinent findings on physical examination: Grade I changes of the fundi were noted. The heart was not enlarged, a fact confirmed by cardiac fluoroscopy, and the sounds were of good quality, but A2 was accentuated. The B.P. averaged 174 systolic and 110 diastolic, with a fall to 114 systolic and 86 diastolic with the use of sodium amytal. Several cold pressor tests indicated a marked hyperreaction. A "Master"[10, 11] two-step test was reported to indicate a coronary insufficiency.

All laboratory data, including P.S.P., urea clearance, dilution and concentration tests, excretory urogram, and examinations of urinary sediment were considered within normal limits.

After sympathectomy the following changes were noted in addition to the patient's voluntary observations that he no longer had headache, dyspnea or precordial pain on effort: A "Master" two-step test, performed two months after operation, was considered normal, as was a cold pressor test. His systolic B.P. has not been noted to exceed 130 systolic and 86 diastolic. He considered his nervousness and irritability minimal.

This patient has been returned to full naval duty.

*Discussion of Hypertension.*—In this group of hypertensives, we are avoiding discussion at present for lack of long follow-up. It is apparent that in this small series, patients have been sufficiently relieved of symptoms so that they have become useful again and, in the case of Naval personnel, have returned to duty. Two cases are cited in detail. Unquestionably, this operation can set

back the hands of the clock for the majority of hypertensives under the age of 50, but whether even the most radical sympathectomy can permanently prevent the tendency for a late reëlevation of blood pressure we are not prepared to venture an opinion. Cases 44 and 41 have shown a tendency in this direction. The operation failed to produce a significant fall in blood pressure in only a single instance (Case 49), where the preoperative evaluation had predicted such a result. In Case 51, with an even more malignant form of hypertension but less organic arterial disease, operation has undoubtedly saved this officer from imminent death and has restored him to useful work for a period of over two years. Three patients have regained blood pressures that are essentially normal, and five that are in an intermediate range.

### F. ANGINA PECTORIS

*Methods of Study.*—These patients were studied by the medical service and, when all efforts to obtain relief of severe cardiac pain by medication failed, they were considered candidates for surgery. As the medical examination showed that they were reasonably good surgical risks, resections of the upper thoracic ganglia on the side of the most severe pain was undertaken without hesitation. Excerpts of the case histories of these two patients are given in Table VI.

TABLE VI

ANGINA PECTORIS

| Pt. | Presenting Symptoms | Duration of Symptoms | Pertinent Findings | Operation | Result of Operation |
|---|---|---|---|---|---|
| 52. James T. VAP Age 44 | Severe precordial pain radiating down left arm. Pain relieved only by morphine, not by nitroglycerine. Attacks occurred t.i.d. | 3 yrs.—but severe 3 wks. | Obese, BP 142 — 100 ECG—abnormal. Heart not remarkable | L. thoracic ganglionectomy, T1—T3 | Horner's syndrome left-sided, dryness. No angina, but warning symptom of epigastric constriction. 3 yrs. |
| 53. Charles C. VAP Age 47 | Unable to work since 1929 because of deep seated griping, precordial sensation brought on by exertion and poorly relieved by nitroglycerine. Pain most noticeable on right side of precordium radiating to right arm. Pain required morphine for relief | 15 yrs. | BP 130 — 94 Heart not enlarged. Sounds indistinct, systolic murmur at apex. Anoxia test caused substernal pain. ECG showed coronary art. disease | R. thoracic ganglionectomy. Inferior cervical through T3 | Completely free of pain on right side. Has not had to resort to morphine. 8 mos. later occ. has mild left-sided pain well controlled by nitroglycerine. 4 yrs. |

*Discussion of Angina Pectoris.*—It is self-evident that few cases of angina pectoris will appear in military personnel on active service. The condition is however, just as frequent in veterans as in civilian patients, and the veterans of the previous war are now entering the age-group of coronary disease. This group of patients is characterized by failure to obtain relief of pain by the usual medication or cardiac regimen; by the marked incapacity of the patient; by absence of cardiac failure or definite cardiac infarction.

In past experience with civilian patients one of us (J. C. W.) has treated 67 by paravertebral injection of 95 per cent alcohol around the upper three or four thoracic sympathetic ganglia, as compared with 74 in whom the corresponding ganglia were removed surgically. With either effective chemical or surgical destruction of these ganglia cardiac pain is abolished. Accurate infiltration of alcohol is more difficult and may be followed by a disagreeable intercostal neuralgia, and it should be reserved for those patients in whom advanced coronary disease or myocardial failure make the surgical approach too dangerous. With present day improvements in the selection of these patients, the advantages of intratracheal ether anesthesia and operation in the sitting position, the proportion that cannot safely be submitted to sympathectomy is steadily decreasing. There has been no report of death attributable to the removal of pain in coronary disease and a vast amount of suffering can be relieved by the coöperation of the cardiologist with the surgeon in suitable cases.

## RESULTS AND CONCLUSIONS

In civilian life the Raynaud's syndrome, hyperhydrosis, and hypertension are often encountered in unstable, emotional individuals, or in those having high vasomotor tone. Psychologic experiences in military life accentuate these phenomena, and the transition from military to civilian life, in turn, may evoke similar responses.

In summary, the results of preganglionic sympathectomy for increasing circulation in Raynaud's syndrome (short of pallid asphyxia), as well as in thromboangiitis obliterans, arteriosclerosis and vascular complications with associated vasoconstriction have been uniformly good. The same is true in hyperhydrosis and in painful states such as causalgia, certain amputation stump neuralgias, and angina pectoris. Our conclusions in hypertension are limited, due to lack of long follow-up, but the immediate results of those observed in a two-year follow-up are: significant lowering of blood pressure; relief of distressing headaches, nervousness and irritability; and the rehabilitation to useful occupations. No fatalities or serious complications have resulted from our operative procedures thus far.

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# GRANULAR CELL MYOBLASTOMA OF THE MAMMARY GLAND*

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ALTHOUGH granular cell myoblastoma is most commonly seen in the tongue, this interesting neoplasm may occur almost anywhere in the body and at any age. In addition to two of these lesions that we have encountered in the skin over the breast region, we have observed five in the mammary gland itself. In this situation this lesion must be distinguished from carcinoma, which it closely resembles. Since granular cell myoblastoma in the breast appears to be benign, requiring only local excision, the differential diagnosis is an important one.

We shall describe our five cases in detail, because they illustrate certain features which may be of aid in the diagnosis of myoblastoma of the breast.

## CASE REPORTS

**Case 1.**—S. P. Unit No. 666228: A Russian woman, age 30, was admitted to the Presbyterian Hospital in August, 1930, for secondary anemia, hemorrhoids, fever of undetermined origin, and obesity. Examination of the breasts at the time did not reveal anything abnormal. Her hemorrhoids were operated upon.

In November, 1931, she discovered a lump in her left breast while palpating it after reading a pamphlet on cancer. Examination showed a hard 1.5-cm. tumor situated in the inner sector of the breast over the 4th interspace 2 cm. from the edge of the sternum. There was no distortion of the contour of the breast and no dimpling of the overlying skin. The tumor was freely movable over the underlying chest wall. There were no enlarged axillary lymph nodes.

On November 16, 1931, under general anesthesia, the lesion was excised. The cut-surface of the tumor was white and opaque. Its edge was not clearly demarcated from the surrounding fat, although it had a lobulated character. A frozen-section was made and it was decided that the lesion was a benign one. The wound healed without incident.

*Microscopic.*—The tumor was composed of cells with small ovoid nuclei and large finely granular cytoplasms. There were irregular coarse collagenous septa among them, but most of the cells lay in immediate contact one with another. The scharlach R stain failed to show lipoid in the cells. The tumor had no capsule. Its structure was clearly that of a granular cell myoblastoma.

*Follow-up.*—The patient was last seen September 26, 1945, 13 years and 10 months after her breast operation. There had been no recurrence of the tumor.

**Case 2.**—A. M., Unit No. 373338: An American Negress, age 19, came to the Presbyterian Hospital first in March, 1933. In January, 1932, her first pregnancy had terminated in cesarian section at another hospital. Four weeks following delivery she had had an abscess in her left breast. It was incised and drained for some time.

Examination revealed an oblique scar of the former abscess in the radius of 11 o'clock just outside the areola in the left breast. The breast was slightly smaller than the right one, but contained no tumor. The patient was found to have syphilis and was given antisyphilitic treatment. She shortly became pregnant again, and was delivered for the second time by cesarian section in May, 1934. A third pregnancy occurred the following year, and was terminated by cesarian section in May, 1935. At this time she was sterilized.

In July, 1937, at the age of 24, she came to the clinic complaining of a tumor in the left breast. She had had no trouble with this breast since the abscess in it in 1933. Previous examiners had not noted any tumor in it.

Examination now showed a firm tumor, measuring 2.5 x 1 x 0.5 cm. in the upper inner part of the left breast. It lay over the second interspace close to the sternal edge. The skin could be moved freely over it, but the tumor seemed to be somewhat attached to the underlying chest wall. On August 9, 1937, under local anesthesia with novocaine, the lesion was biopsied. It lay in breast tissue and was not encapsulated. It was adherent to the pectoral fascia. The whole lesion was removed. On section, the tumor was firm, fibrotic, and grayish-yellow. The wound healed well.

*Microscopic.*—The lesion was made up of cells with small nuclei and voluminous cytoplasms filled with fine granules. There were no vacuoles, and the scharlach R stain failed to show lipoid. The lesion was a characteristic granular cell myoblastoma. It had no capsule, and infiltrated the adjacent breast tissue.

*Follow-up.*—The patient was last seen on October 30, 1945, eight years and two months after operation. There was no recurrence.

Case 3.—L. J., Unit No. 714878: A West Indian Negress, age 37, came to the Presbyterian Hospital, July 12, 1943, complaining that she had had a tumor in the right breast for seven years. She recalled striking her chest against the corner of a table at that time. There was no subsequent ecchymosis, but a few days after the blow she noted the tumor for the first time. It had not changed appreciably in size during the following seven years. It had never been painful nor tender.

Examination showed a hard, rather well-circumscribed tumor lying over the fourth right interspace close to the edge of the sternum. It measured 1.5 cm. in diameter. Although no dimpling of the overlying skin could be demonstrated, the tumor was fixed, to an abnormal degree, to the underlying pectoral fascia, for when the pectoral muscles were contracted with the patient sitting upright the tumor and the breast tissue around it were pulled upwards sharply. No such elevation of the corresponding part of the left breast could be demonstrated. When the patient lay in the supine position contraction of the right pectorals markedly limited the movability of the tumor over the chest wall. There was no distortion of the contour of the right breast, and the right nipple and areola were normal.

On November 18, 1943, under avertin, gas and oxygen anesthesia, operation was undertaken. All preparations had been made for a radical mastectomy should it prove to be necessary. A short incision was made directly over the tumor and a small wedge, measuring 2 x 10 mm., was excised from the surface of the lesion after careful hemostasis. Frozen-section revealed that it was a granular cell myoblastoma. The whole tumor was, therefore, excised. Its cut-surface was finely granular, and grayish-white with a tinge of yellow. Its edge was sharply defined from the surrounding fat (Fig. 1). The wound was closed with subcuticular and skin sutures of silk. Healing was uneventful.

*Microscopic.*—The tumor lay in mammary tissue, and had no true capsule. It was made up of rather large cells, with finely granular cytoplasms and small regular nuclei, lying in masses and strands in a fairly well developed collagenous stroma. The scharlach R stain did not show any lipoid in these cells. The tumor was clearly a granular cell myoblastoma.

*Follow-up.*—The patient was last seen October 8, 1945, just short of two years following operation. There was no evidence of recurrence.

Case 4.—Unit No. 739836: A Russian born Jewess, first came to the Presbyterian Hospital in 1928, when she was 47 years of age. She was found to have hypertensive cardiovascular disease, and mild diabetes, which was controlled without insulin. In 1930, she developed chronic tonsillitis, and tonsillectomy was done without incident. She failed to follow her diet and gained a good deal of weight as the years went by. In 1935, she was




FIG. 1.—Gross appearance of myoblastoma of the breast (Case 3).

given insulin, but, by 1938, she was having so much trouble with her diabetes that she had to be hospitalized for a while. Protamine insulin controlled the diabetes, but as time went on she developed evidence of a considerable degree of coronary sclerosis.

In February, 1944, at the age of 63, she discovered a tumor in her left breast. It presented on the inferior aspect of the large dependent breast just cephalad to the inframammary fold. It was, therefore, concealed when the patient sat erect and in this position the only evident abnormality was slight elevation of the breast (Fig. 2). It was very evident with the patient in the supine position, however, as a projecting tumor situated over the fifth interspace half way between the sternal edge and the nipple line (Fig. 3). It was very hard, and measured 4 cm. in diameter. The tumor and the breast tissue in which it lay were relatively fixed to the underlying chest wall. When the breast was pushed medially toward the tumor a definite dimple appeared in the skin over it. No enlarged axillary nodes were detected.

A presumptive diagnosis of carcinoma of the breast was made and all preparations completed for a radical mastectomy. Fortunately, a biopsy was done, a small wedge being removed from the surface of the lesion for frozen section. The only feature of the gross appearance that suggested something unusual was the fact that the cut-surface of the tumor was whiter than most carcinomas (Fig. 4). When the frozen section revealed that the lesion was a granular cell myoblastoma it was excised locally and the wound closed. Healing was uneventful.

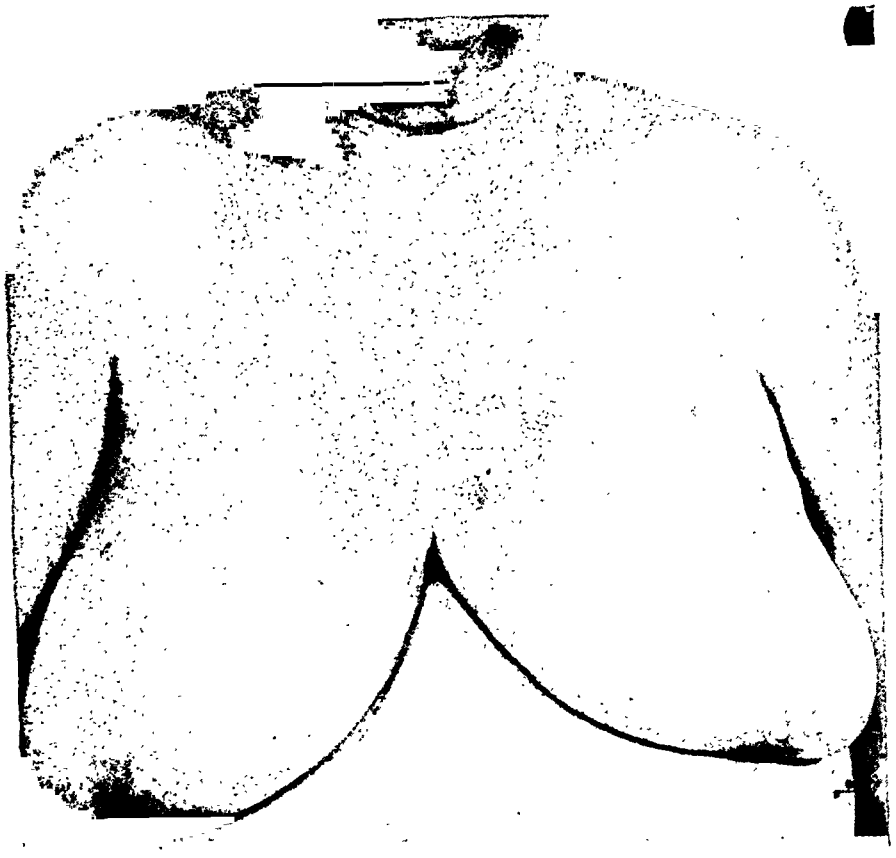
*Microscopic.*—The tumor was made up of myoblasts with small oval nuclei and large finely granular cytoplasms (Fig. 5). The cells lay in solid masses and strands, often in immediate contact with one another without any intervening collagenous reticulum. The scharlach R stain failed to show any lipoid in the cells. The edge of the lesion was sharply defined against the adjacent mammary tissue, but there was no true capsule.

*Follow-up.*—The patient had had no recurrence of her myoblastoma when she was last examined on March 19, 1946, two years following operation.

The fifth case was observed by one of us (C. D. H.) at the Memorial Hospital some years ago. At that time the lesion was classified as a primary *xanthoma* of the breast, and it was reported under that name in 1932. At the time we did not know that, in 1926, Abrikossoff had traced the histogenesis of these tumors to muscle cells and named them "myoblastic myomas." When we came to realize the correctness of Abrikossoff's view of the origin of these tumors, restudy of this tumor of the breast left no doubt in our minds that it was a typical granular cell myoblastoma.

**Case 5.**—C. B. T., an unmarried Irish woman, age 74, was referred to Dr. James Duffy at the Memorial Hospital for treatment, August 7, 1930.

FIG. 2



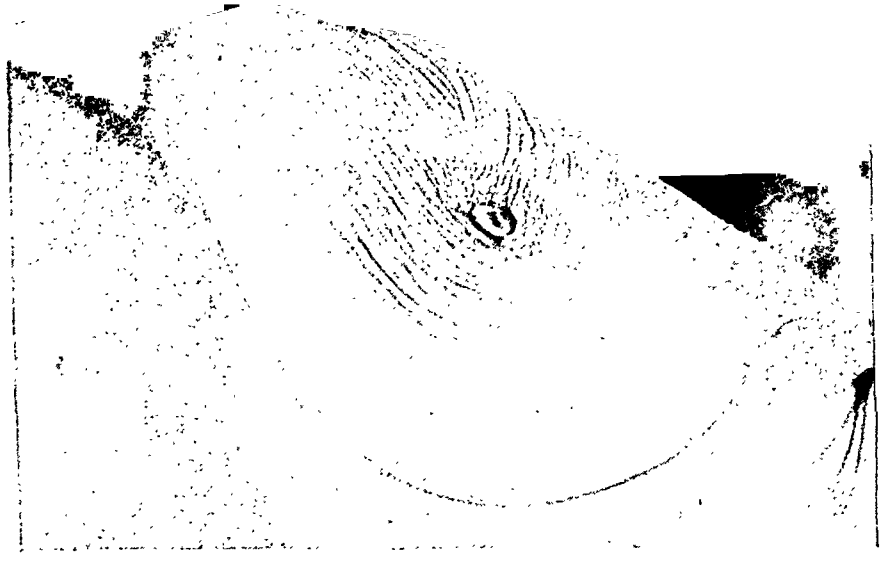


FIG. 3

FIG. 2.—Elevation of the breast caused by myoblastoma (Case 4).
FIG. 3.—Myoblastoma projecting from the breast, as seen in contour with the patient lying supine (Case 4).

Five years previously, about 1925, she had first observed a small lump in the inner portion of her left breast. It had grown very slowly. She had had no pain in it. Examination showed a large tumor in the upper inner quadrant of her right breast (Fig. 6). It measured 9 cm. in diameter and was elevated 4 cm. above the surface of the breast. The skin over it was reddened and shiny. The middle of the tumor was soft, suggesting a central area of necrosis. It was slightly movable over the underlying chest wall. The nipple was not retracted. There were no nodes palpable in the right axilla or supraclavicular space. In the left axilla several small soft nodes were felt. A clinical diagnosis of carcinoma of the breast with impending ulceration was made.




FIG. 4—Gross appearance of myoblastoma of the breast (Case 4).

The patient was found to have, in addition, diabetes and chronic nephritis. It was, therefore, decided by Doctor Duffy that interstitial radiation would be the best treatment. Accordingly, August 26, 1930, steel needles containing a total of 85 millicuries of radon filtered by 0.3 mm. of gold and 0.2 mm. of steel were inserted into the breast and a total of 7,200 millicurie hours given. A reaction, limited to reddening and slight desquamation of the skin over the tumor, developed during the following weeks. The tumor decreased markedly in size during this period. By March, 1931, seven months after treatment, the

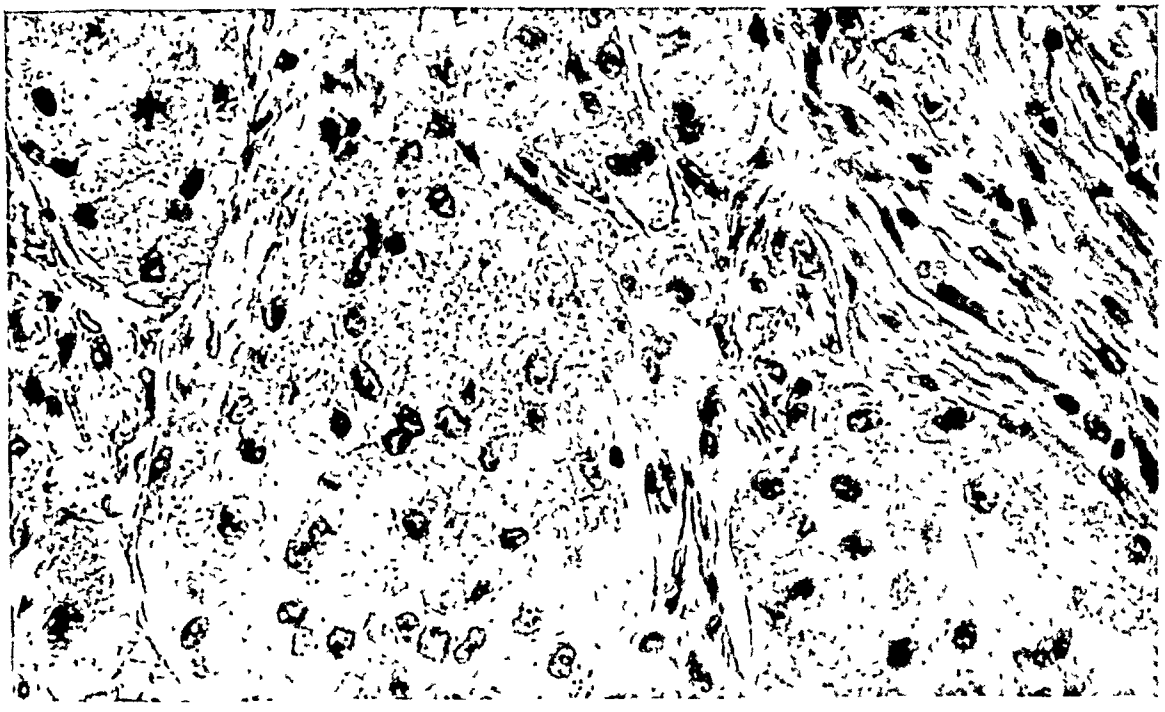


FIG. 5.—Microscopic appearance of myoblastoma of the breast (Case 4).

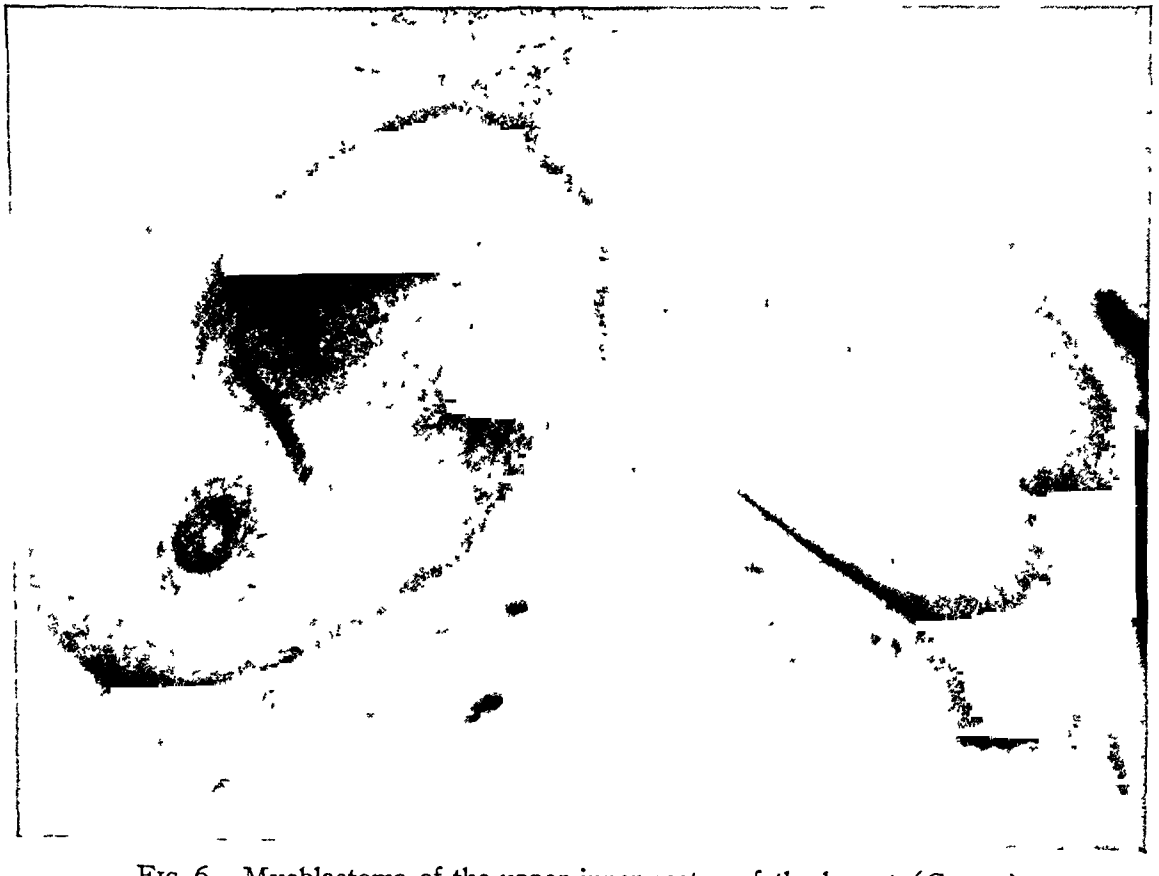


FIG. 6.—Myoblastoma of the upper inner sector of the breast (Case 5).

contour of the breast was almost normal. The reddish discoloration of the skin had completely disappeared. Of the tumor, only an indefinite area of induration in the breast tissue remained. It was decided that although there had been remarkable regression, a residuum of the tumor persisted. Since the diabetes had been brought under control and was no longer a contraindication to operation, a simple mastectomy, under local infiltration anesthesia with novocaine, was carried out on June 2, 1931. The tumor appeared to be encapsulated, and measured 6 x 4 x 6 cm. Its cut-surface was soft, reddish, and granular. Recovery was uneventful.

*Microscopic.*—The tumor was composed of large, round or polyhedral pale cells lying in the interstices of a rather prominent fibrous stroma. The cytoplasms of the tumor cells were finely granular or vacuolated. The nuclei were small and dark. Large portions of the tumor were necrotic: in these only degenerating tumor cells and amorphous débris remained. A sudan III stain showed droplets of the dye in the cytoplasms of some of the tumor cells. The tumor is a granular cell myoblastoma in which there has been a good deal of degeneration.

*Follow-up.*—One year after operation there had been no recurrence of the tumor.

We have been able to find but five previous reports of granular cell myoblastoma of the breast. All of them lack details. These reports follow:

Cheatle, writing in 1931, mentioned a "single solid tumour in the breast of a woman, age 38." It was circumscribed but not encapsulated, and the cut-surface had a characteristic (*sic*) yellow appearance. He classified it as a *xanthoma*. No follow-up was mentioned.

Abrikossoff, reported an undoubted case in his 1931 paper. His patient (No. 4 in his series) Mrs. V., was a Jewess, age 55, the wife of a physician. She was admitted, November 26, 1927, for a tumor of the left breast. She had had a cholecystectomy 16 years previously, and was a diabetic. She had noticed the tumor in her left breast two months previously. At that time it was a small firm nodule. It grew slowly, and was painless.

Examination showed a firm, well circumscribed, movable, hazel nut-sized tumor, situated in the upper outer sector of the left breast. The tumor was not adherent to the skin. The breasts were of average size and dependent.

On November 28, 1927, the tumor was excised. It was a rounded nodule, 2 x 1.5 cm., very firm, light gray in color, and with a somewhat fibrous cut-surface. Microscopic examination showed it to be a granular cell myoblastoma.

No follow-up was included.

Meyer described another myoblastoma of the breast in 1932. The tumor (No. 2 in his series) was removed from the breast of a three-months pregnant woman on December 8, 1931. It was the size of a peanut, was rather well-circumscribed, and lay close beneath the skin over the breast. It penetrated the glandular tissue of the breast, but did not extend down to the pectoral muscle. The wound healed primarily. Microscopic examination showed the lesion to be a granular cell myoblastoma. There had been no recurrence six and one-half months later.

Geschickter mentioned myoblastoma of the breast in his 1934 paper on tumors of muscle. He stated that he had observed three myoblastomas of the breast, and included a photograph of the gross specimen of one (Path. No. 39034). This lesion was said to be firm and encapsulated. Its location in the

breast was not stated. There was no follow-up. No details regarding the other presumed cases were presented.

Gray and Gruenfeld reported a myoblastoma of the breast in 1937. In their case (No. 5 in their series) no clinical details were available, except that the large encapsulated tumor was removed from the breast of a white woman, in the Out-patient Department. The tumor measured about 10 cm. in diameter, had a grayish color and a firm consistency. Microscopic examination showed it to be a typical granular cell myoblastoma. There was no follow-up.

DISCUSSION.—The granular cell myoblastoma of the breast is, so far as experience goes, a benign tumor. It is impossible to ignore the fact that this tumor type may on occasion become malignant and metastasize as has been pointed out by Ravich, Stout and Ravich, but this is probably such an uncommon event that it is justifiable to treat the tumor as benign when it is encountered. In the breast its greatest importance depends probably upon the fact that it may closely simulate carcinoma of the breast. Unless the surgeon and pathologist are aware of this similarity myoblastoma may be mistaken for carcinoma and the breast needlessly sacrificed.

It is apparent from our five cases that myoblastoma occurring in the breast can produce all of the clinical signs of early carcinoma. The lesion is hard. It is relatively fixed in the breast tissue surrounding it. It may be abnormally attached to the underlying pectoral fascia. It may cause dimpling of the overlying skin. The gross appearance of the lesion is enough like carcinoma to betray most pathologists into making this diagnosis if they depend upon the gross appearance alone, without taking the precaution of making a frozen-section. The closest scrutiny will show that myoblastoma is more sharply circumscribed than most carcinomas, and that its cut-surface is whiter and more uniform than the grayish chalk-streaked surface of the typical carcinoma. These differences, however, are slight and easily missed.

We have made it a practice to make immediate frozen-sections of all lesions removed for biopsy from the breast, because of the similarity in gross appearance of myoblastoma, and several other benign lesions that occur in the breast, to carcinoma. Myoblastoma is easily recognizable in a good frozen-section. In our two most recent cases, Nos. 3 and 4, the diagnosis was made in this way. We do not use the aspiration method of biopsy in the diagnosis of breast lesions, for we have found it to be unreliable.

The source of the muscle cells from which these myoblastomas arise in the breast is an intriguing, although perhaps a somewhat theoretical question. Abrikossoff traced the origin of these tumors to striated muscle, and the fact that their most common site is the muscular substance of the tongue supports this concept. But as our knowledge of the myoblastomas has developed it has become obvious that they sometimes occur in regions of the body where there is no muscle tissue of any sort. The gum of the newborn infant is a good example. We have observed three granular cell myoblastomas in this location, and there are reports of several similar cases.

The breast is likewise without muscle tissue, except for a network of smooth

muscle fibers in the subareolar region and in the nipple, and encircling the terminal ducts beneath the nipple. Seitz made a special study of the musculature of the breast and concluded that there is no striated muscle tissue in the breast proper. A diagram showing the location of our four myoblastomas (Fig. 7) makes it clear that the tumors were all in the periphery of the breast far from the areolar and nipple region.

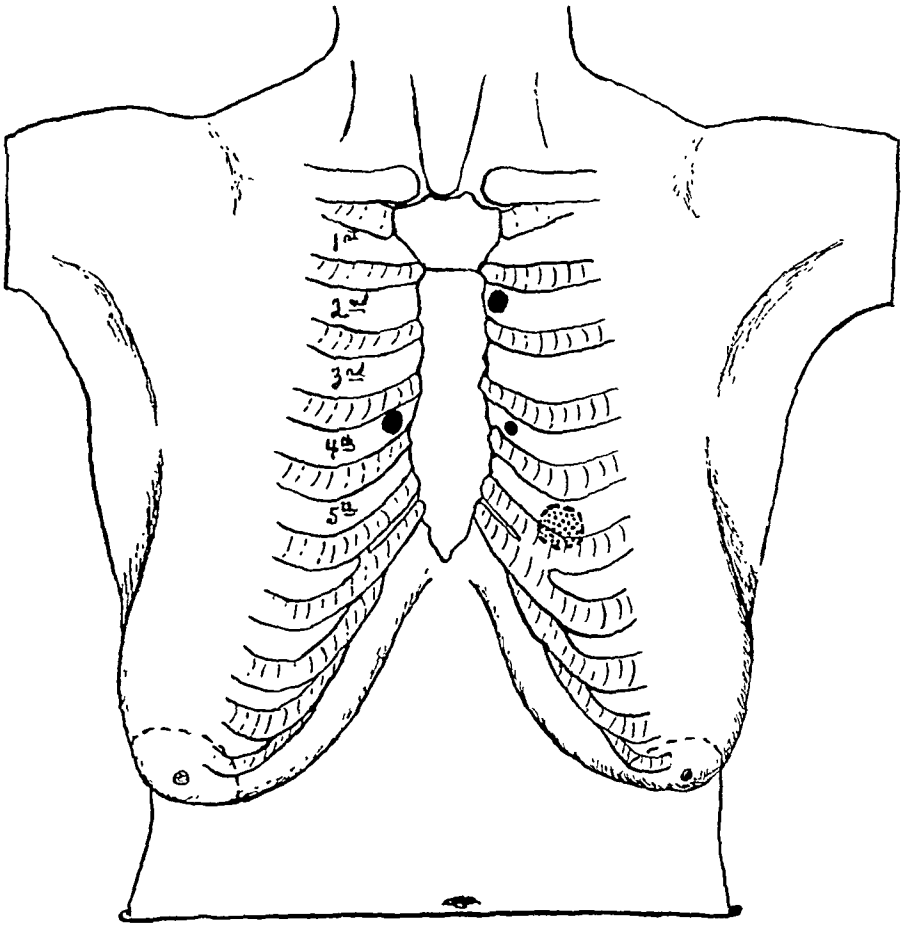



FIG. 7.—Diagram showing the location, in relation to the sternum and intercostal spaces, of the myoblastomas in Cases 1, 2, 3, and 4.

Our search for muscle tissue from which these tumors might have developed, therefore, turns to the musculature of the chest wall. All four of our tumors appeared to have developed within the breast itself superficial to the pectoral fascia, and, therefore, superficial to the pectoralis major muscle.

The occurrence of these myoblastomas adjacent to the sternum suggests a possible origin from the *sternal* muscle, a small anomalous muscle of great variability which occurs in from 1 to 10 per cent of Europeans. Eisler describes this muscle as extending vertically or diagonally across the upper chest close to the sternum, superficial to the pectoral fascia.

Another possible origin is from the platysma. Its fibers extend in a fan-like manner down over the chest wall from the neck. They may, according to Eisler, extend as far caudally as the fourth rib. These muscle fibers lie upon the superficial fascia and are, therefore, immediately adjacent to the mammary gland which lies beneath this fascia.

It may be of diagnostic significance that all four of the granular cell myoblastomas of the breast that we have studied personally, and in which we know the exact site of the lesion, developed in the medial half of the breast. Until more cases have been reported we are not justified in concluding that these tumors do not occur in the lateral half of the breast, but the questions is worth bearing in mind.

SUMMARY

Five new cases of granular cell myoblastoma of the breast are described and the case reports of five previously reported cases reviewed.

The importance of these tumors comes from the fact that they closely simulate, in both their clinical characteristics and gross appearance, carcinoma of the breast. Biopsy and frozen-section are required to differentiate the two lesions.

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# COMBINED ROENTGEN RADIATION AND SURGICAL TREATMENT OF LARGE BENIGN GIANT CELL TUMORS OF BONE

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IN THE VOLUMINOUS LITERATURE about benign giant cell tumor of bone the reader is frequently cautioned against the combination of radiation therapy and surgery in the management of this tumor. The reason appears to be that radiation therapy would jeopardize the process of tissue repair. On the basis of our experience, we believe this concept to be erroneous. It is, therefore, the purpose of this paper to present the therapeutic technic and results obtained in the management of seven patients with proven diagnoses of benign giant cell tumor of bone which presented difficult problems in treatment. The treatment entailed a combination of roentgen radiation which was followed by surgery comprising removal of the tumor with thorough curettage and then filling the defect with bone grafts. Neither chemical nor thermal cauterization was employed.

In those benign giant cell tumors of bone which are readily accessible and can be removed without sacrifice of function, we believe in immediate and complete excision. Examples of such tumors are those observed in the vertebral spinous and transverse processes.

In 1936, the first patient was treated by the combination of preoperative roentgen radiation followed by surgery, and the results were so satisfactory that when three years later we were consulted by a young woman, age 26, who had been advised amputation because of an unusually large, rapidly-growing benign giant cell tumor in the lower end of the femur, the same procedure was adopted with a satisfactory result.

The remaining five cases exhibit varied clinical aspects of the same condition, and were treated in a similar manner.

## RADIATION THERAPY

All of the patients in this group have received approximately (details in case reports) 1,800 r, measured in air, delivered through two portals using 200 K.V.P., 1 mm. of copper filtration, 50 cm. distance, and a cone large enough to more than cover the lesion, to deliver a total dose of 900 r measured in air to each skin area. This quantity of radiation when properly filtered and given in divided doses is not enough to produce skin or tissue changes, yet is adequate to temporarily arrest the growth of the tumor and to allow cortical healing.

Roentgenograms taken in the first four to six weeks following radiation treatment usually reveal further bone atrophy and apparent progression of the tumor, but in eight to ten weeks following radiation, beginning appearance of calcium deposits is evident, plus replacement and thickening of the cortex. Also, if there originally was protrusion of the tumor into the soft tissue, this mass is diminished in size. In eight to 12 weeks after radiation, bone cortex is again intact and sufficiently developed to permit thorough curettage and removal of the tumor tissue.

Postoperative roentgen radiation has not been given except in one patient (Case 4), a 58-year-old laborer, who had a large tumor of the upper end of the tibia, in whom the operation was planned in two stages because of his extremely poor physical condition. Following the first stage, comprising very thorough curettage and removal of the tumor tissue, it was later considered unwise to again submit him to surgery and this man was, therefore, given additional roentgen radiation.

## OPERATIVE PROCEDURE

The affected area of the bone is exposed and a window cut in the cortex of minimal size consistent with thorough visualization of the cavity. Tumor tissue is then carefully and very thoroughly curetted out. Every effort is made to protect the cartilage of the joint. The cavity is next tightly packed with bone grafts which have meanwhile been removed from the tibiae and/or ilium. Thereafter, the fibrous envelope which had previously been dissected off the area where the window was cut is carefully approximated with chromic sutures and the remainder of the wound closed in layers and a plaster encasement applied of an extent sufficient to adequately support the extremity, as for example, when the lower end of the femur is involved, a hip spica. In one patient (Case 7), the operation advocated by Codman was employed as a final procedure, removing a considerable portion of the wall of the cavity and leaving a flap of periosteum on the concave side of the bone defect.

In comparison with surgery on similar cases who did not receive preoperative radiation therapy, the operator has been much impressed by the relative avascular character of the tumor tissue in this group of patients. Furthermore, the tumor is comparatively firm as opposed to the usual friable tissue removed when radiation is not employed. The technical details of the curettage are thereby rendered simpler and we believe the surgeon is much less apt to leave bits of tumor tissue behind.

## REPORT OF CASES

**Case 1.**—This 40-year-old paper mill employe was admitted, June 24, 1936, because of pain and marked disability in relation to the left knee, of four months' duration. Roentgenograms on admission (Fig. 1) revealed a tumor of the distal left femur and at one point there was evidence that the process had broken through the cortex.

Preoperative roentgen ray treatment was given from July 28 to July 31, 1936, using the following factors: 200 K. V. P., 50 cm. distance, 1 mm. of copper and 1 mm. of

aluminum filtration, port 15 cm., round cone, giving a daily dose of 400 r measured in air. Four treatments were given for a total of 1,600 r.

At operation, August 3, 1936, the frozen-section diagnosis was benign giant cell tumor of bone, which was confirmed on the permanent section. Thorough curettage and removal of the tumor tissue was performed, no cauterization, and the cavity then packed with bone grafts removed from the right tibia. The wound healed by first intention.

The patient was last examined October 1, 1945. Figure 2 exhibits excellent recalcification of the lateral condyle of the femur and the contour thereof was fairly normal. There was no evidence of recurrence. Roentgenograms of the lungs were negative. He had no disability in relation to the knee, and there were no changes in the skin.



FIG. 1.—(Case 1): Preoperative roentgenogram revealing benign giant cell tumor involving the lower aspect of the femur. Symptoms of four months' duration. Complete disability on admission.

**Case 2.**—A 26-year-old girl student was admitted to the Clinic, January 10, 1939, with a two and one-half-year history of pain and disability in relation to the left knee region. She was operated upon elsewhere in 1936 because of a presumed internal derangement, and one of the semilunar cartilages removed. She did not improve. Finally, in October, 1936, a definite soft-tissue swelling appeared in the vicinity of the knee. It was found to involve the bone on roentgenologic examination. A biopsy was performed elsewhere. The pathologic report was giant cell sarcoma (this slide was obtained prior to the patient's admission and gone over by Dr. Shields Warren who reported benign giant cell tumor of bone without any evidence whatsover of malignancy).

Throughout 1937 and 1938 she was disabled, wearing a plaster encasement much of the time, and had been in bed continuously since October, 1938. During this interval following the surgery she had roentgen ray treatments, also given elsewhere, details not known. In addition, during this period she apparently experienced two pathologic fractures. Because amputation had been advised, the patient came to the Clinic for another opinion.

Roentgenologic findings on admission were those as shown in Figure 3. The leg, protected in an encasement, was markedly thickened and swollen throughout, especially around the region of the knee, with evidence of postradiation changes in the skin. There was marked pain in the distal thigh and knee region, and inability to move the knee joint. The patient appeared to be in excellent general condition. Roentgenograms of the lung were negative.



FIG. 2.—(Case 1): Anterior and posterior roentgenograms nine years and eight months after operation. Note recalcification of the lateral condyle of the femur and a relatively normal contour, with no evidence of recurrence of tumor. Normal function of knee joint.

In view of the definite assurance this was a benign lesion, we felt every effort should be made to save the extremity. An exhaustive study of various possible methods of surgical treatment was made. In view of the size of the tumor and the fact that an appreciable portion of its periphery did not exhibit any cortex, and especially because it was felt that supplementary roentgen radiation would aid in recalcifying and limiting the lesion, it was decided to carry out initial intensive roentgen ray treatment, to be then followed by surgical excision of the tumor tissue, preservation of as much of the cortex as possible, and filling the area with bone transplanted from elsewhere in the body. Therefore, the patient received a total of 1,800 r through two portals, using the same factors employed in the preceding case. There was pronounced increase in the calcification and apparent beginning repair of the tumor area (Fig. 4).

Operation was performed, May 18, 1939, when the entire cavity was thoroughly and carefully curetted. Cauterization was not employed, and the cavity was filled with bone grafts transplanted from both tibiae. Convalescence was uneventful following surgery and the wound healed by first intention. By September 19, 1939, she had progressed to walking in a supporting caliper and the roentgenograms showed progressive fusion of the bone grafts (Fig. 5).

On February 14, 1940, a small defect was observed on the anterior surface, about 4 cm. above the patella, which had not previously been noted. It was the opinion of the roentgenologist (H. F. H.) this should be treated by radon seeds, which was carried out on March 14, 1940.

The roentgenograms taken on February 21, 1946 (Fig. 6), indicate a healed lesion and no evidence of recurrence. The patient clinically is well, active, working full-time

and the only disability is that occasioned by limitation of knee motion which had been accepted as inevitable when first seen, due to deformity of the articular cartilage. Post-radiation skin pigmentation is evident but no other abnormality.

**Case 3.**—This 42-year-old clerk was admitted, October 20, 1939, because of persistent soreness and discomfort in the left ankle region of six months' duration, initiated by two episodes of spraining the ankle. There was persistent swelling, becoming very marked if she was on her feet for any length of time. The general condition of the patient was

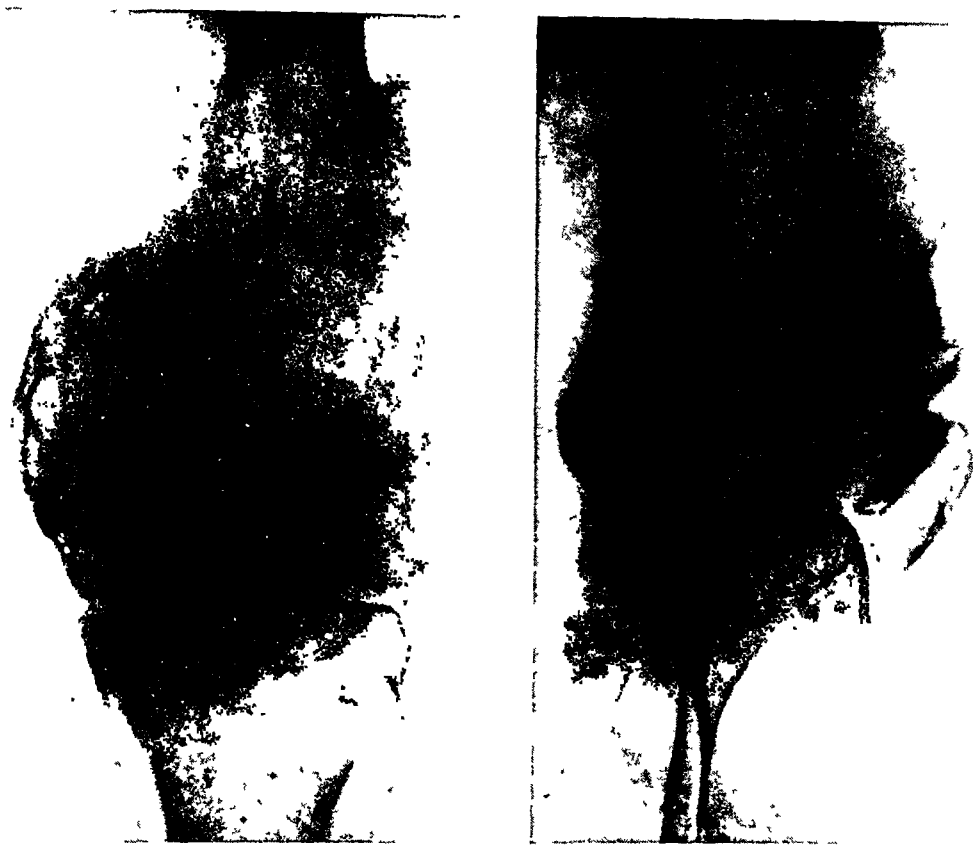


FIG. 3.—(Case 2) : Preoperative roentgenogram of a rapidly growing benign giant cell tumor of the lower end of the femur. Note absence of cortex over an appreciable part of the lesion and the irregularity of the articular cartilage of the femur.

excellent. The admission roentgenograms (Fig. 7) indicated a benign giant cell tumor. The patient was, therefore, started on roentgen radiation treatment, receiving a total of 1,500 r to each of two lateral portals, using the same factors as previously described, except for a 10 cm. cone.

At operation, January 22, 1940, the tumor mass was found to occupy the anterior and lateral three-fourths of the lower end of the tibia, but had broken through into the soft tissues, especially in the vicinity of the lateral malleolus and extended down alongside of but not into the ankle joint. The tumor tissue was carefully curetted out, no cauterization done, and the area packed with bone fragments removed from the right tibia. The wound healed by first intention. The patient was discharged as ambulatory, with crutches, from the hospital February 18, 1940.

The last physical examination and roentgenologic observations were obtained on February 7, 1945, at which time she presented a normal appearing ankle, no visible skin changes, with no swelling, normal motion of the joint and no symptoms. The roentgenograms (Fig. 8) exhibit no evidence of recurrence of the tumor.

Case 4.—This 58-year-old laborer was admitted to the Clinic, May 17, 1943, because of pain in the region of the left knee, of two years' duration. In 1941, he had been operated upon elsewhere for removal of the tumor in the region of this left knee which the family understood was not malignant. Within six months' time symptoms began to recur, had progressively become more marked, and on admission he showed marked disability in relation to the left lower extremity, with pronounced muscle atrophy and a 70-degree flexion contracture of the left knee joint. His general condition was not favor-

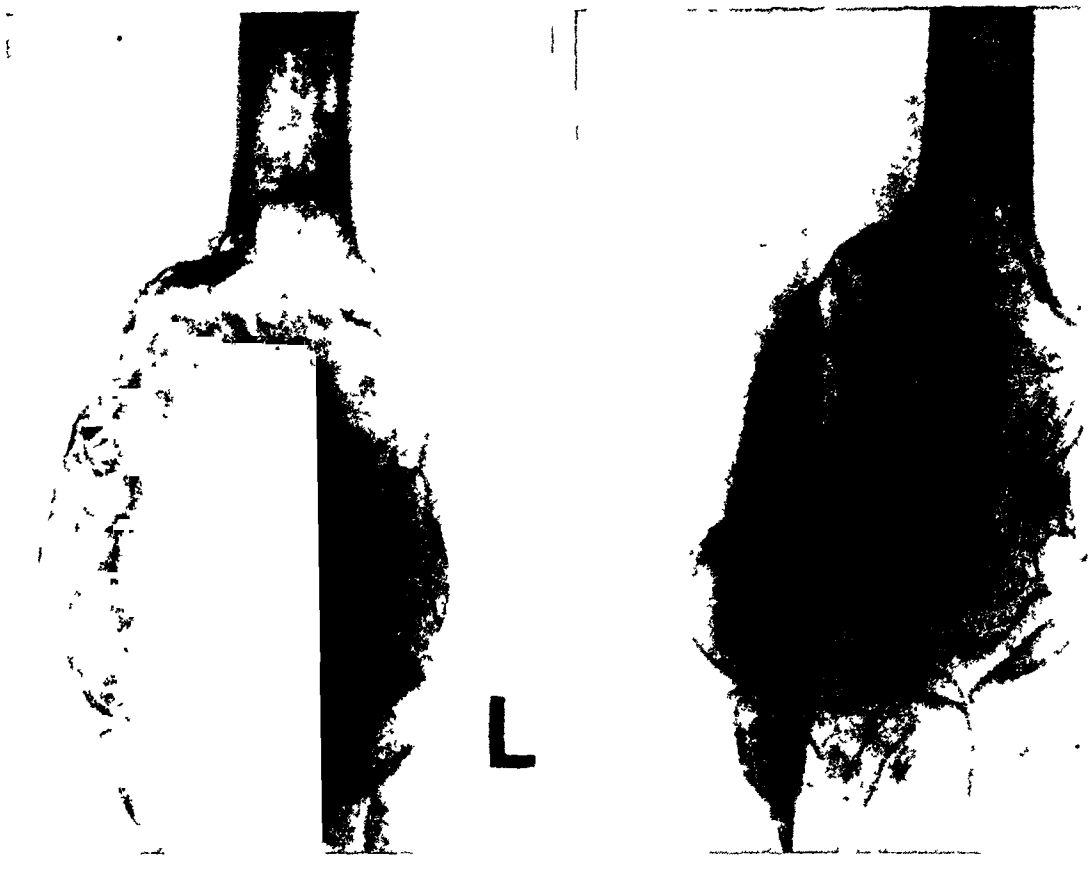



FIG. 4.—(Case 2): Roentgenographic appearance of tumor area four months after institution of roentgen radiation therapy. Observe definite increase in calcification and presence of a definitive cortex surrounding the tumor mass.

able for any major surgery as, while he stated his age to be 58, physiologically, he was a good ten years older and revealed evidence of a relatively marked generalized arteriosclerosis.

Figure 9 exhibits the condition seen on admission. Note the large tumor mass projecting into the popliteal space, which was the basis for the acute symptoms, causing pressure on the posterior tibial vessels and nerves. Roentgenograms of the lungs were negative.

He was, therefore, placed on initial preoperative roentgen ray treatment. On October 5, 1943, the first-stage procedure was carried out. (The operation was initially planned in two stages because of the general poor condition of the patient.) At that time the tumor mass was approached from the posterior aspect, removed, and the tumor within the upper end of the tibia cleaned out. The tumor extended down to the middle third of the lower leg, much farther than was evident in the roentgenograms. Pathologic section confirmed the diagnosis of benign giant cell tumor. By utilization of a plaster encasement it was possible to almost entirely correct the flexion deformity. The wound healed by first intention, but because of the unsatisfactory general condition, it was then decided



FIG. 5.—(Case 2) : Roentgenographic appearance of the tumor area four months after operation. Multiple bone grafts are beginning to coalesce. There is some deformity of the contour of this part of the bone, but the articular cartilage, though still irregular, has been preserved.

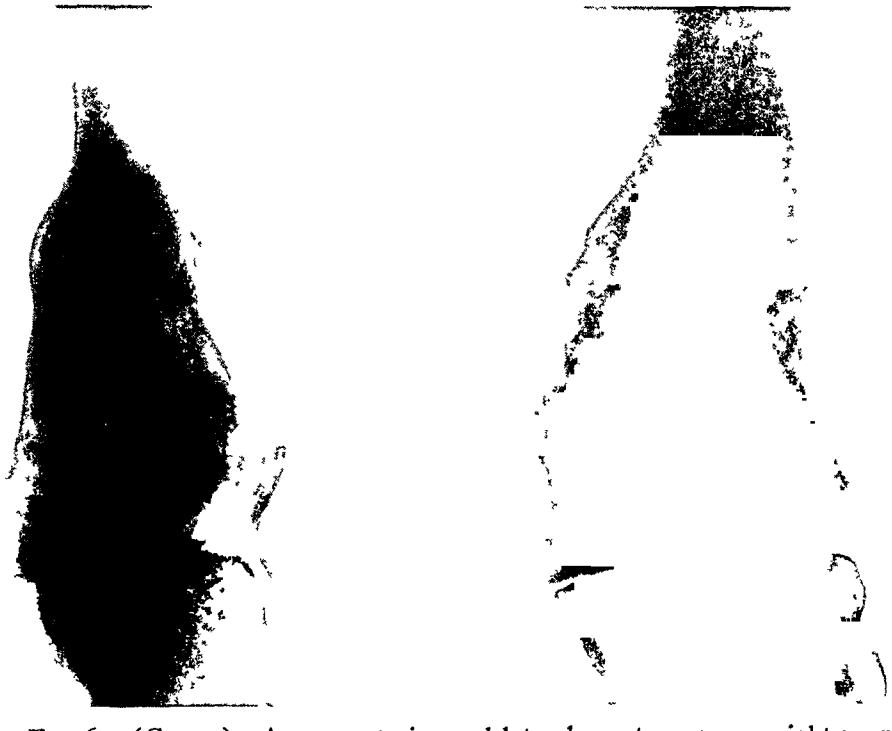


FIG. 6.—(Case 2) : Anteroposterior and lateral roentgenograms eight years following institution of treatment. There is no evidence of recurrence of tumor. Femoral condyles are relatively square and cause limitation of motion in the knee. Patient is exceedingly active and carries on a normal life.

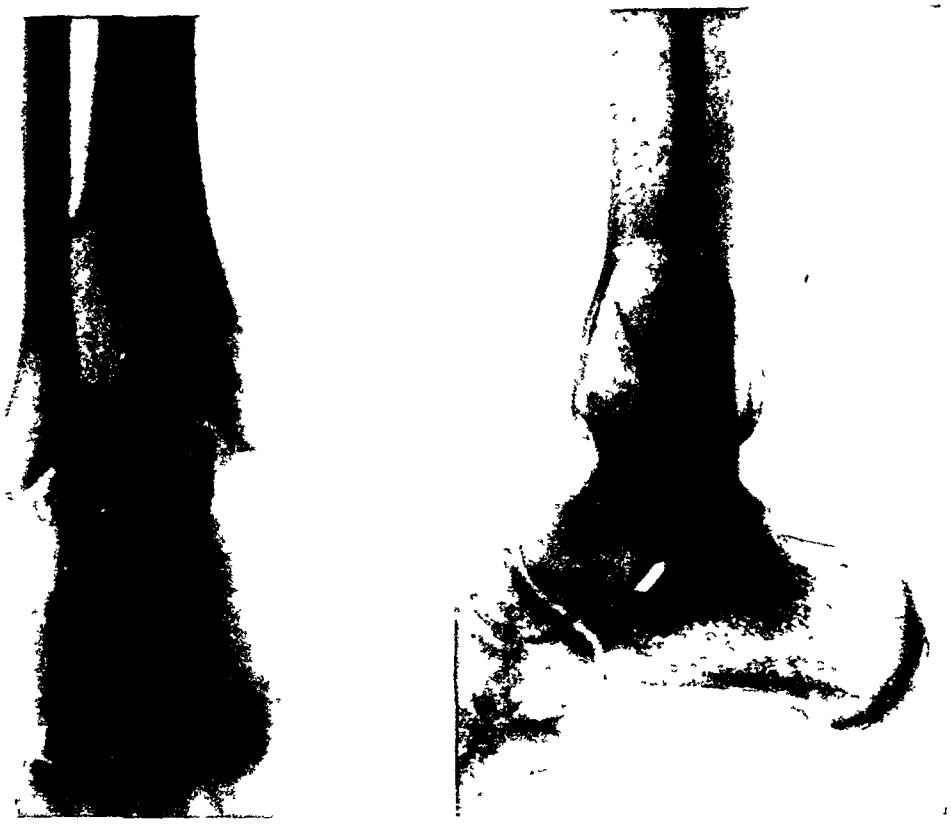


FIG. 7.—(Case 3) : *Roentgenograms exhibiting benign giant cell tumor involving the distal end and lateral aspect of the tibia.*



FIG. 8.—(Case 3) : Postoperative anteroposterior and lateral roentgenograms five years after operation. Asymptomatic. Clinical examination including that of the skin is negative. No evidence of recurrence of tumor.

further surgery was contraindicated. Instead of packing the cavity with bone grafts, further roentgen radiation therapy was planned (this is the only patient on whom this program of treatment was followed).

The patient received 1,300 r to each of two ports (anteroposteriorly and posteroanteriorly) preoperatively and 600 r postoperatively to each of two ports laterally. The last examination was on September 17, 1945, at which time there was a 10-degree instead of a 70-degree flexion deformity of the knee, but there was full flexion from this position. He walked without pain or discomfort. The roentgenogram (Fig. 10) did not reveal evidence of recurrence of the tumor.



FIG. 9.—Case 4) : Roentgenogram exhibiting extensive involvement of the upper end of the tibia by benign giant cell tumor. Note large mass projecting into the popliteal space. Pronounced disability.

**Case 5.**—This 20-year-old housemaid was admitted to the Clinic, February 21, 1944, with the complaint of pain and disability of the left knee region. A pathologic fracture of the lateral femoral condyle occurred on May 22, 1943. A biopsy performed elsewhere revealed a benign giant cell tumor of bone. She was again operated upon on July 17, 1943, elsewhere, and the tumor curetted and bone chips inserted. There was apparently satisfactory progress until February 7, 1944, when roentgenograms revealed a marked increase in cystic changes in the bone and it was thought a malignant tumor was present; amputation was advised.

On clinical examination, the patient revealed an almost complete loss of function in the knee due to pain, with a very marked flexion contracture. The roentgenogram (Fig. 11) in our opinion indicated that it was still a benign giant cell tumor. This was later confirmed when Dr. Shields Warren examined slides of tissue removed at the previous operation.

Preoperative roentgenotherapy was directed through three skin portals, two lateral 10 cm. each and one anteroposterior 15 cm. A total of 1,500 r measured in air was

delivered to each skin area in divided doses, to give a total of 4,500 r, giving a daily dose of 150 r to each portal so as not to produce skin damage. In Figure 12 note the marked increase in bony trabeculation and calcium deposit in the five months following roentgen radiation.

On October 9, 1944, the tumor area was exposed, carefully curetted, no cauterization, and packed with bone grafts. Pathologic report revealed "benign giant cell tumor with unusual osteoid activity, probably due to preceding trauma." It was not considered to be malignant. The patient convalesced uneventfully following this procedure, and was discharged home, October 20, 1944, in a plaster encasement to protect the extremity, walking with crutches.

The last observation was on January 15, 1946, when the roentgenogram (Fig. 13) revealed progressive calcification of the involved area. The external contour of the operative site remains smooth. At this time she was walking without crutches and had no pain or swelling of the knee, and there was no clinical evidence of recurrence. Unable to move the knee on admission she now has 80-degree flexion from full extension. With continued exercises, a further increase in motion is anticipated. Roentgenograms of the lungs remain negative. The skin of the radiated area is of normal appearance.

**Case 6.**—An 8-year-old girl was admitted to the Clinic, December 11, 1944, because of a persistent swelling of the left hand which had been first noted in August, 1944, and since that time had progressively increased in size to the point where when first seen there was marked loss of function of the hand. Examination revealed a diffuse, pronounced swelling of the region of the fourth metacarpal of the right hand and the roentgenograms (Fig. 14) were characteristic of a giant cell tumor which on the basis of the history was rapidly increasing in size. Inasmuch as all the findings indicated a benign process, she was, therefore, started on preoperative roentgen ray therapy, receiving a total of 600 r through a shielded port so as not to affect the epiphyses.

February 27, 1945, the tumor was exposed by a dorsal incision, cleaned out carefully, no cauterization, and packed with bone grafts. No attempt was made to crush in the walls of the cavity, desirable from a cosmetic point of view, because of the inevitable subsequent disturbance to the metacarpal phalangeal articulation. Pathologic report was benign giant cell tumor, with radiation reaction.

The wound healed by first intention. The patient was thereafter observed at intervals, the last time on January 26, 1946, when she showed normal motion of the wrist and fingers. The swelling had almost entirely disappeared and the skin of the radiated area revealed no change. Roentgenograms (Fig. 15) exhibit a healed lesion and no further evidence of disturbed epiphyseal growth.

**Case 7.**—A 45-year-old housewife was admitted to the Orthopedic Service, August 15, 1944, with the complaint of pain in the left knee of three months' duration. The pain was so severe she could walk only with crutches and even then with great difficulty. The roentgenograms (Fig. 16) suggested a malignant lesion, as did the history, but at biopsy, August 23, 1944, a definite diagnosis was made of benign giant cell tumor of bone.

Thereafter she received radiation therapy, 1,500 r to each lateral port, for a total of 3,000 r. On December 21, 1944, she was operated upon in the manner described. The pathologic report of the tissue removed revealed benign giant cell tumor with extensive fibrosis due to radiation reaction. The wound healed by first intention and she was discharged home in a plaster encasement, walking with crutches, but returned seven weeks later because she was experiencing some thigh discomfort. Inspection of the site of the wound revealed a definite cellulitis for which she was immediately hospitalized, and within three days developed a small sinus from which serous-like material discharged. It was cultured but no growth obtained. Gradually this reaction subsided and she was again discharged home. The symptoms recurred and she finally was again readmitted and, June 2, 1945, the entire area of the tumor including transplanted bone was cleaned

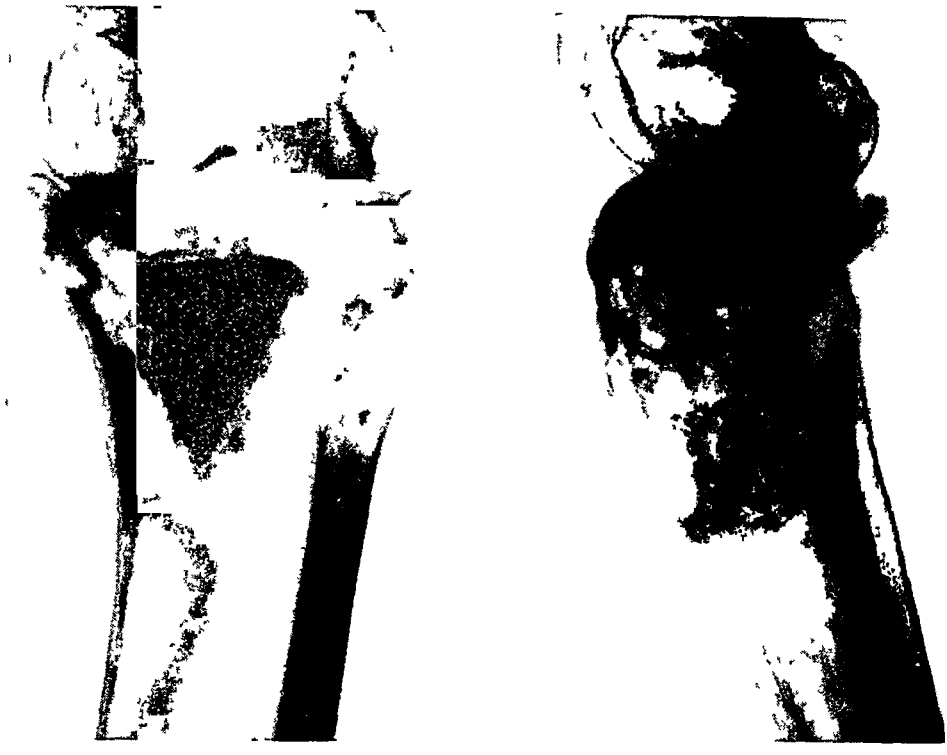


FIG. 10—(Case 4) : Appearance two years and four months following first-stage operation. Because of poor physical condition an attempt at bone graft was not carried out. Asymptomatic except for a 10-degree persistent flexion contracture of knee joint. Excellent function

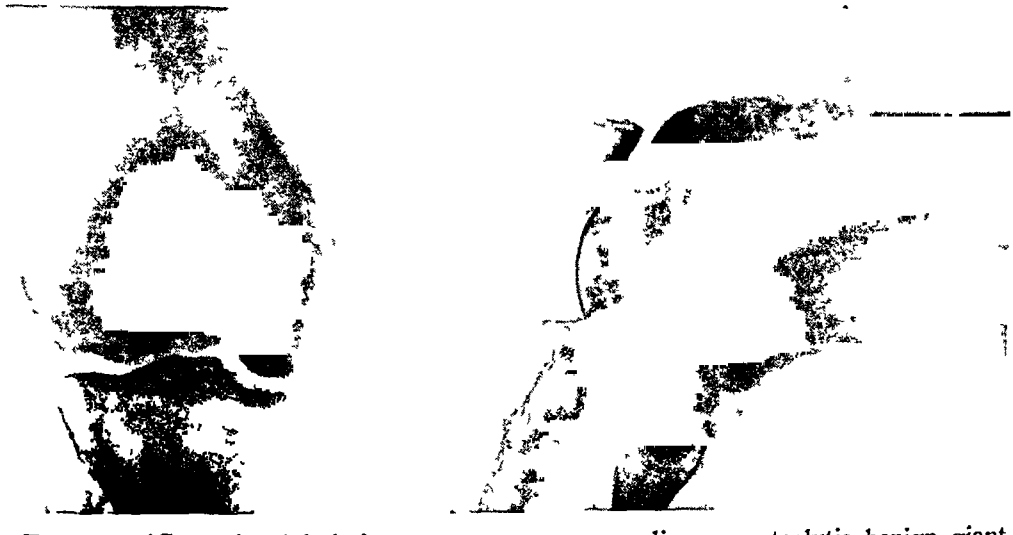


FIG. 11.—(Case 5) : Admission roentgenogram revealing an osteolytic benign giant cell tumor of the lower end of the femur. Observe large mass in the lateral view in the posterior aspect of the femur.

out and much of the wall of the cavity cut away (Fig. 17). A periosteal flap was turned in over the defect. The pathologic report of the material removed at this operation was fibrosis with foreign body reaction. There was no definite evidence of tumor.

Since the above procedure the wound has remained healed and in the last roentgenograms (Fig. 17), February 21, 1946, there is no evidence of tumor recurrence nor of osteomyelitis.

Because of persistent pain affecting the entire extremity, it was believed the patient

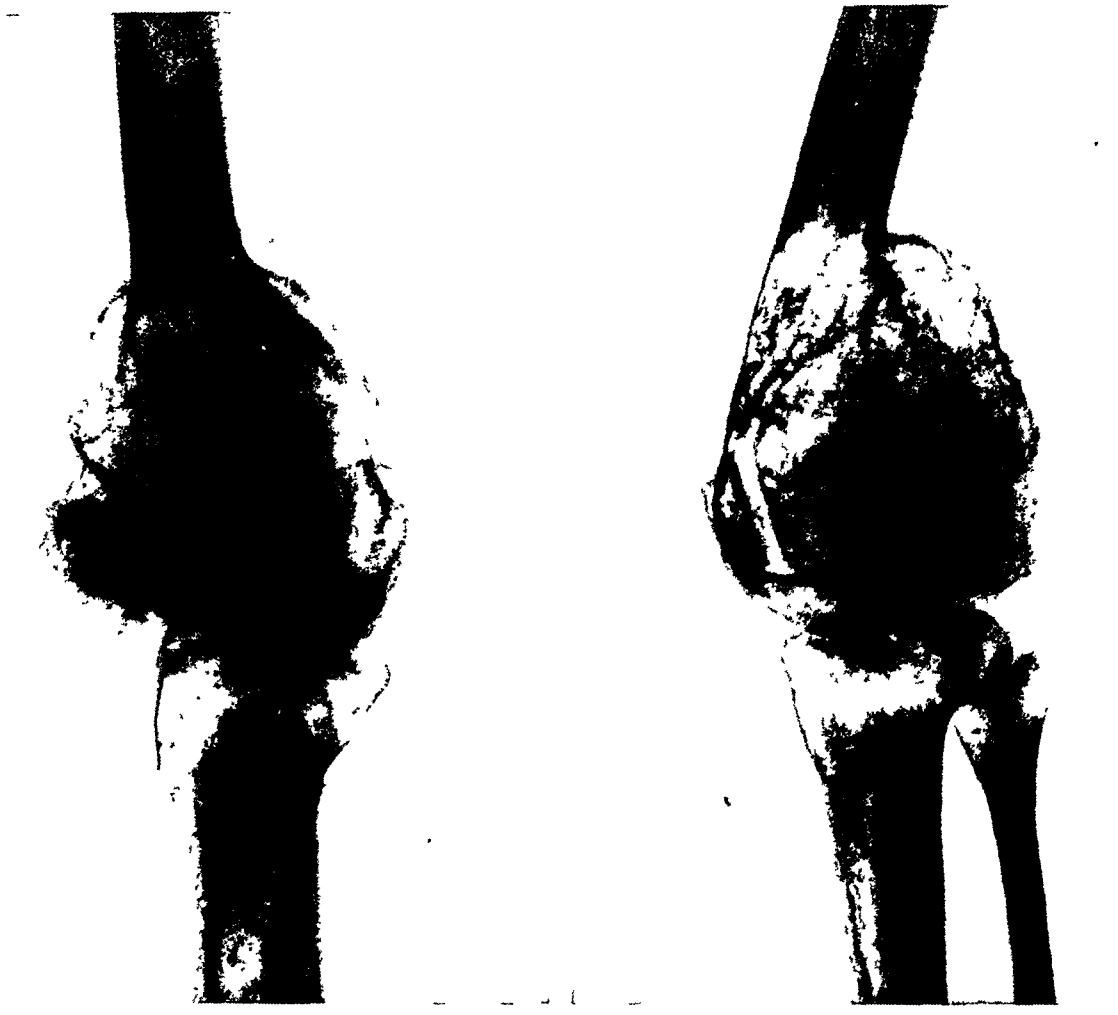


FIG. 12.—(Case 5) : Roentgenograms seven months following institution of roentgen radiation therapy. Marked increase in calcification and formation of a definite cortex about the tumor mass.

might also have a true sympathetic dystrophy. This was confirmed by procaine block of the lumbar sympathetic chain and finally a left lumbar sympathectomy was performed by the general surgical service on August 8, 1945, since which time she has been comparatively asymptomatic and is progressively increasing the range of motion in the knee. Patient continues to protect the extremity by walking with crutches, due to the extensive removal of bone. There is no evidence of skin radiation reaction.

## RESULTS

Seven patient have received combined roentgen ray and surgical treatment for proven benign giant cell tumor of bone. All are living and well, and over an average period of 4.7 years, exhibit no evidence of recurrence. The longest follow-up is nine years eight months, the shortest one year.

One patient (Case 4) received postoperative radiation treatment because it was not possible to complete the surgical procedure due to the patient's poor physical condition.

All of the operative wounds healed by first intention. In one patient (Case 7), seven weeks after operation, what originally appeared to be a mild cellulitis developed about the site of the previously healed incision. A serous-like dis-



FIG. 13.—(Case 5) : Roentgenograms one year and ten months following institution of roentgen ray treatment and one year and three months following operation. No evidence of recurrence of tumor. The irregularity of the lateral femoral condyle persists. Progressively increasing function of knee joint. Skin over this area negative for any changes.

charge then appeared which on culture revealed "gram-positive cocci in clumps which would not grow out on subculture." Some further attempts to culture this discharge revealed no growth. Under conservative management, the wound healed, the patient returned home, but later it again broke down, necessitating a secondary operative procedure. This wound also healed by first intention and has remained healed for nine months, the patient meanwhile ambulatory. At no time in this patient was there evidence of an osteomyelitis.

The function of the joint adjacent to the tumor has been preserved in all

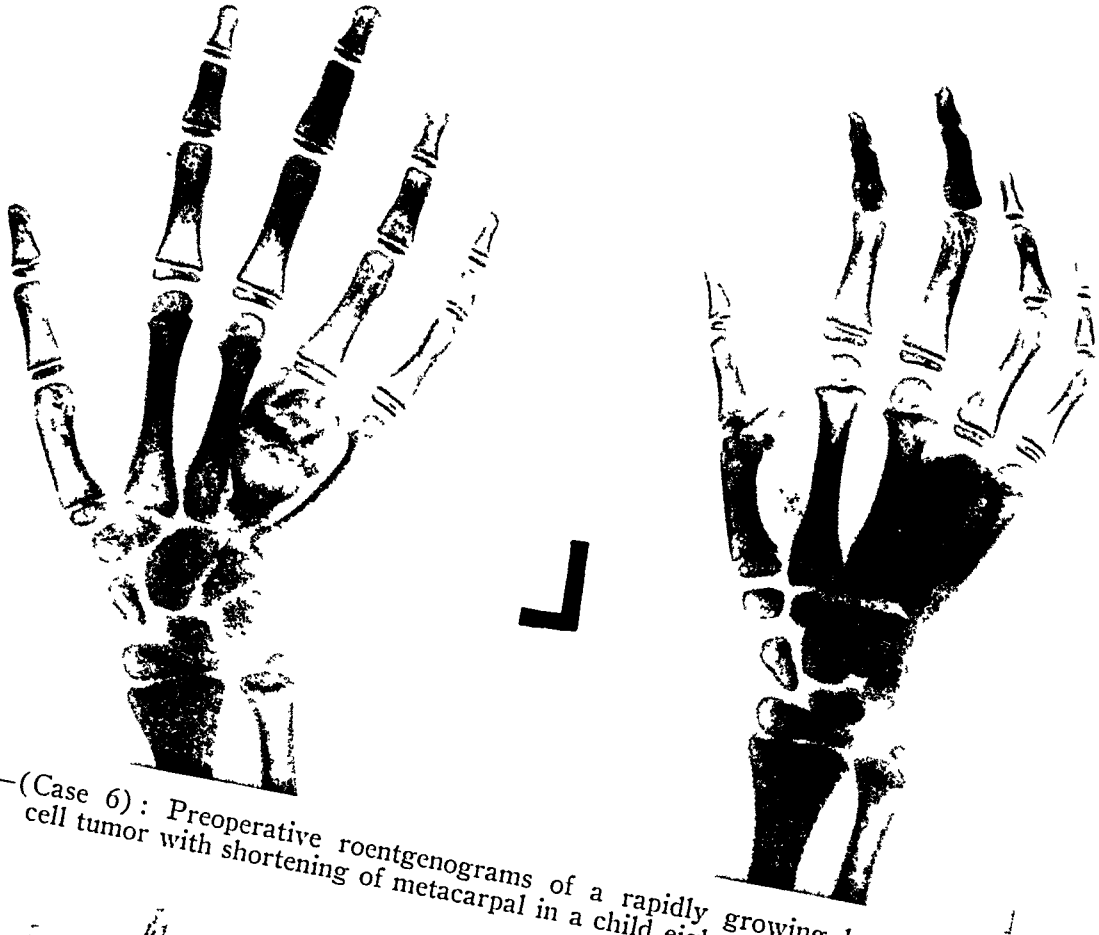


FIG. 14.—(Case 6): Preoperative roentgenograms of a rapidly growing benign giant cell tumor with shortening of metacarpal in a child eight years old.

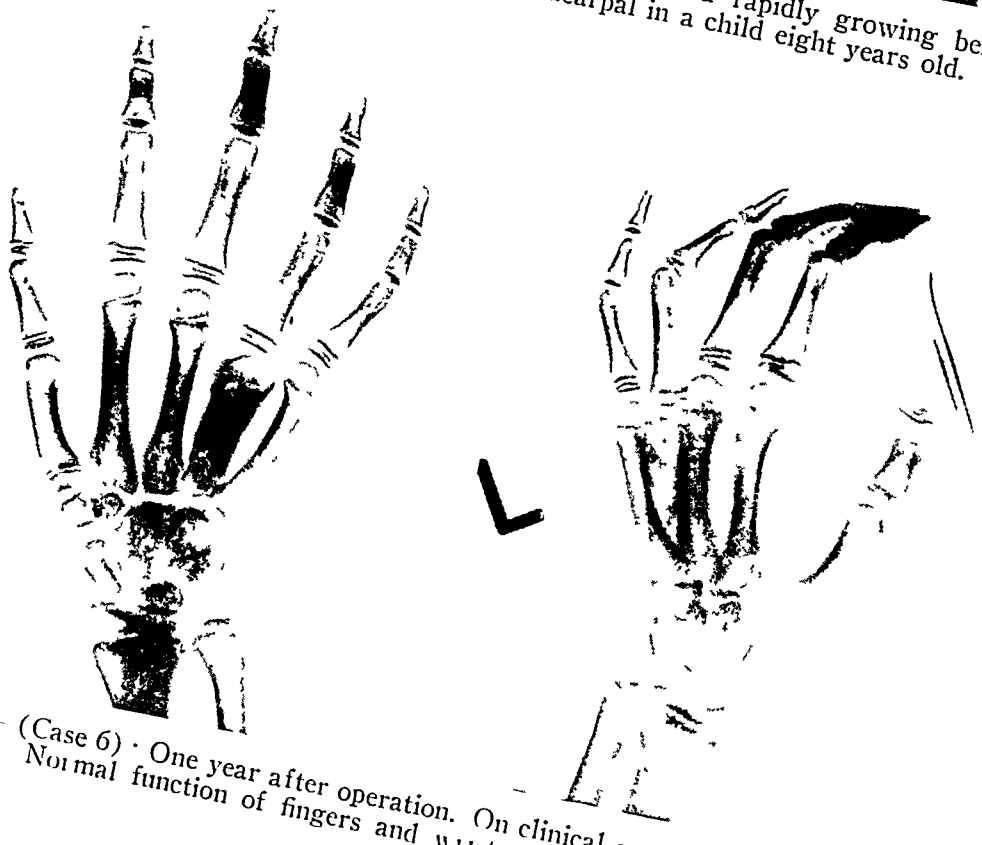


FIG. 15.—(Case 6): One year after operation. On clinical examination the swelling is not apparent. Normal function of fingers and wrist. No evidence of recurrence. Skin negative.

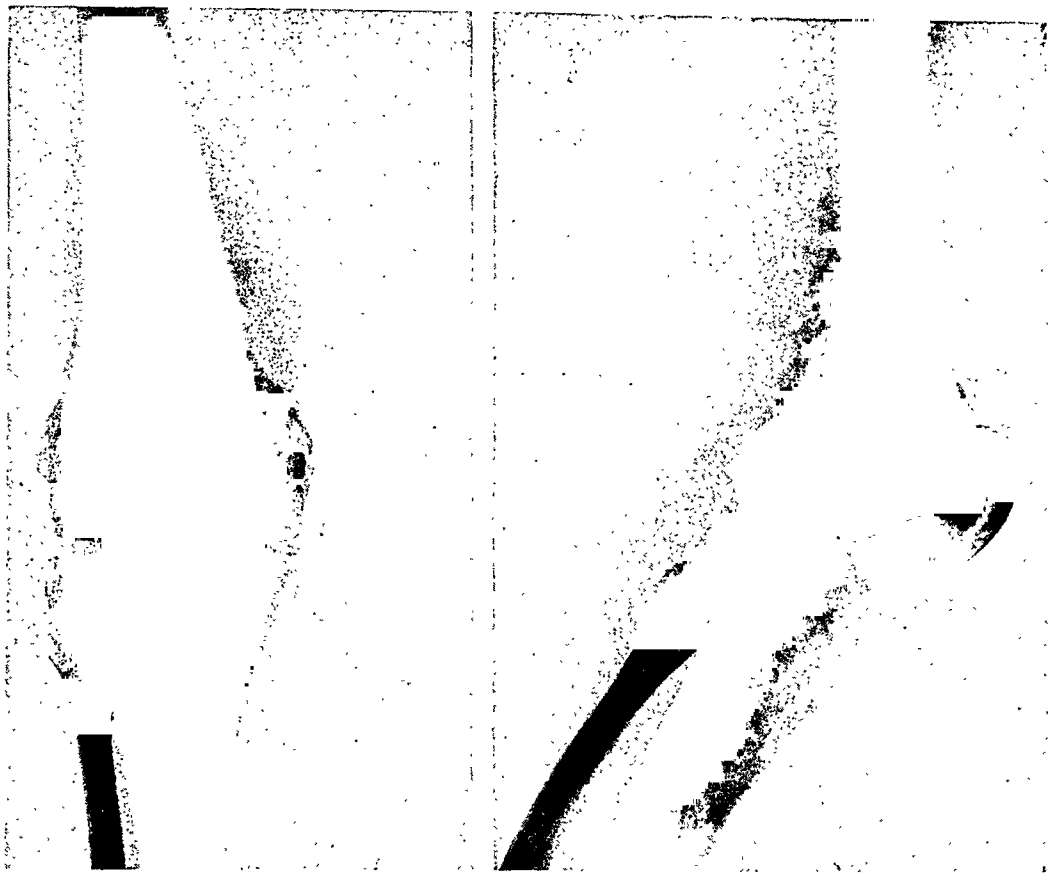


FIG. 16.—(Case 7) : Admission roentgenogram of an osteolytic, completely disabling benign giant cell tumor of the lower end of the femur, which suggested malignancy; this disproved by biopsy.

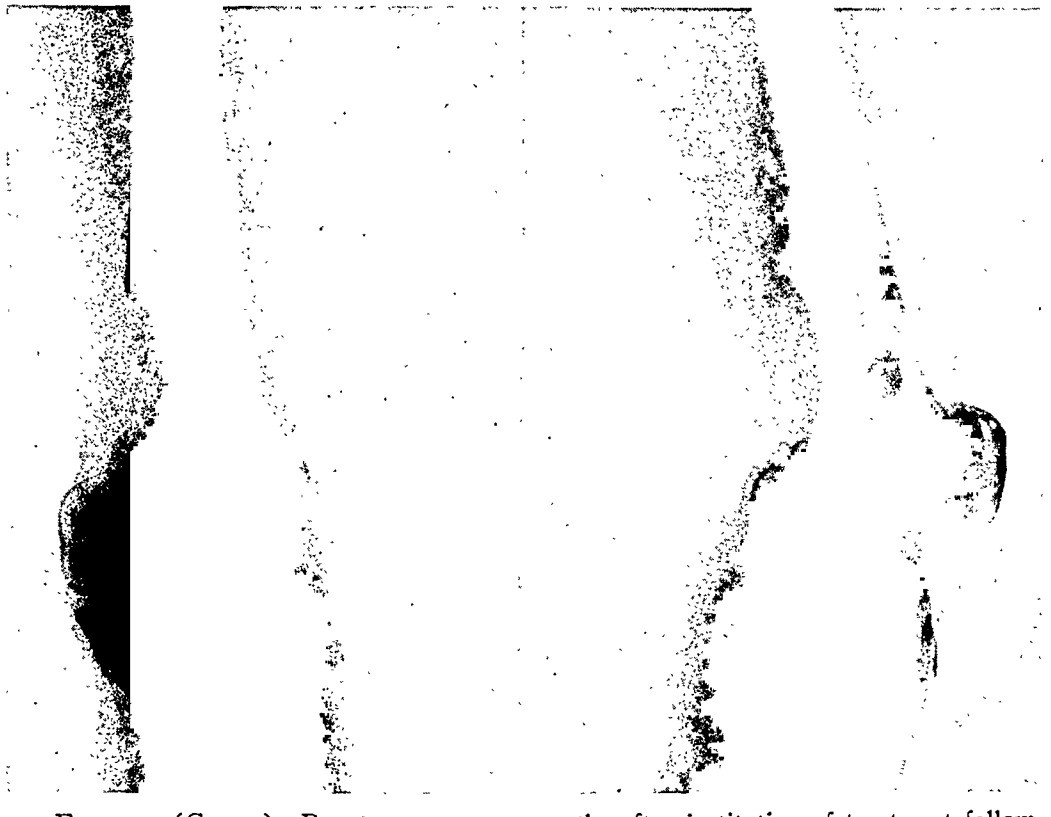


FIG. 17.—(Case 7) : Roentgenogram 17 months after institution of treatment following a supplementary procedure that necessitated removing previously placed bone grafts. Wound healed *per primam*. Progressively increasing function of knee joint, now one-half normal. No symptoms and no evidence of recurrence.

patients who on admission revealed a normal appearing articular surface in the roentgenogram. In one patient (Case 6) there appeared to be marked distortion of the anatomy of a metacarpal phalangeal joint. But one year later the fingers and wrist exhibit normal function.

In Case 2 there was definite skin change noted on admission. This was caused by previous roentgenotherapy which in our opinion was given without adequate filtration and as a result of using large skin portals. Roentgen radiation following admission through several small ports did not produce further skin damage.

COMMENT.—Following a review of a large series of cases collected by the Registry of Bone Sarcoma, Codman, in 1937, stressed the fact that a study of these cases indicates the essentially benign nature of the tumor. He concluded that expansion and progress of the tumors are due to their pulsation and not to the malignant quality of their cells. Codman postulated that the structure of a giant cell tumor was analogous to that of a sponge in that there are no walled blood vessels and the corpuscles circulate through the interstices of the tumor as if it were a sponge; hence, this whole sponge pulsates and tends to expand in bony walls by destroying the rigid boundaries. He, therefore, concludes, "it is very important to pay scrupulous attention to stopping the blood supply of the tumors."

On the basis of our experience in operating upon these tumors with and without preoperative roentgen radiation there is no question but that the character of the tumor tissue following roentgenotherapy is very much less vascular when radiation treatment is administered. Also, the histology of the tumor following radiation reveals a marked fibrosis, with pronounced reduction in the cellular character of the tumor.

As a further aid in controlling the blood supply of the tumor area we now plan at operation to utilize the various forms of blood fractions which have become available to check hemorrhage.

It is to be emphasized that the radiation therapy given before surgery in the manner as outlined, did not interfere with wound healing. In one patient (Case 7) it might be argued that the roentgen ray treatment was responsible for the cellulitis that appeared seven weeks after operation. It was true that at the time we were not able to culture an organism. On the other hand, the whole process was an inflammatory one in every way compatible with an attenuated infection or aseptic necrosis. When finally reoperated upon, the wound healed promptly and has remained healed.

It is pertinent to note that no malignant changes have developed in these patients or in any other benign bone lesions which we have subjected to radiation treatment.

We also believe it is extremely important that the involved extremity, with appropriate splintage, be subjected to as near normal use as soon as possible. This program stimulates bone repair, and with the institution of intensive active muscle exercises, hastens recovery.

## SUMMARY AND CONCLUSIONS

Seven patients with benign giant cell tumors of bone have been treated by combined roentgen ray and surgical management. In each instance not only has the extremity been saved and there has been no evidence of recurrence of the tumor but the affected extremity is a useful member.

Roentgen radiation therapy, as herein described, has not interfered with the reparative processes of the tissues following surgery.

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# EPITHELIOMA OF THE ANUS*

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EPITHELIOMA OF THE ANUS is a lesion which is not encountered frequently. It occurs usually as a disorderly growth of squamous cells, but the basal cell and mixed varieties also are seen. The tumors are found at or near the mucocutaneous margin, or within the anal canal, or situated principally within the rectum, sometimes having only a slight gross relation to the epithelium below the pectinate line. Similar growths are also found within the large intestine, clearly distinct from the anus.

Perhaps because no one person has had much experience with these tumors, there seems to be no clear understanding among the medical profession of how they should be treated. The literature only adds to the confusion. Papers have appeared in this country reporting 92 cases from the Mayo Clinic, and ten cases from the Lahey Clinic, and there have been reports of cases treated at l'Institut du Radium in Paris, and others from clinics in London and Germany. These reports, however, do not give in detail the circumstances associated with the lesions which they discuss, or a clear impression of the virtues of the various methods of treatment employed. Cattell and Williams, from the Lahey Clinic, recommend an abdomino-perineal resection with inguinal node dissection "in every case of an operable tumor in which cure is possible and feasible." The 20 cases treated at l'Institut du Radium naturally received radiation therapy, and the difference in reported results of the two methods is not striking. Broder's classification has been suggested as a basis for deciding what form of treatment to use, but this recommendation has by no means been widely adopted. It is with the purpose of clarifying the rationale for the choice of one or more of the various possible forms of treatment that this review was undertaken.

The cases reviewed are 37 which were seen at the Presbyterian Hospital from 1918 to 1944, inclusive. A statistical analysis of so few cases, or even of all the cases appearing in the literature, would be valueless. The method of study, instead, has been to analyze carefully these cases in which the treatment, the follow-up result, and many of the circumstances attending the individual lesions are known. Among the 37 cases, the sex incidence was nearly equal. The age incidence by decades was surprising, as over one-fifth of the patients were under 40 years (Table I).

Table II shows how the cases have been classified. There is little to be learned from the first two groups, composed of patients who received no treatment or had no follow-up record and of those to whom frankly palliative therapy was given. The other three groups are further analyzed.

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The cases referred to in this paper which received radiotherapy, received this treatment under the care of Dr. Maurice Lenz, Professor of Clinical Radiology, College of Physicians and Surgeons, Columbia University.

Although it is often from his poor results that the surgeon learns most, not much information can be obtained from the unsuccessful cases in this series. Some of them perhaps should have been classified with the group which received palliative therapy. The two postoperative deaths do not give a fair estimate of the danger of the abdomino-perineal operation, because one of the deaths occurred in a patient greatly emaciated as the result of chronic ulcerative colitis, in whom the epithelioma was only a small incidental lesion,

TABLE I

AGE INCIDENCE

| Age | Cases | Age | Cases |
|---|---|---|---|
| 20–29 | 2 | 60–69 | 5 |
| 30–39 | 6 | 70–79 | 6 |
| 40–49 | 9 | 80–89 | 1 |
| 50–59 | 7 | Unknown | 1 |

TABLE II

GROUP CLASSIFICATION

| | |
|---|---|
| No treatment (5), or no follow-up record (1) | 6 |
| Palliative treatment only | 9 |
| Unsuccessful treatment | 9 |
| Recent cases, still alive (under 3 years) | 7 |
| Survived 5 years or more | 6 |
| Total | 37 |

TABLE III

UNSUCCESSFUL CASES

| | | |
|---|---|---|
| Abdomino-perineal resection: | | 4 |
| Postoper. deaths | 2 | |
| Nephritis—9 mos. | 1 | |
| Persistent tumor | 1 | |
| Perineal proctectomy | | 1 |
| Radiation (one lived 4 years with the disease) | | 4 |
| Total | | 9 |

TABLE IV

RECENT CASES, STILL ALIVE (UNDER THREE YEARS)

| Case | Treatment | Size of Tumor |
|---|---|---|
| M. G. | Perineal proctectomy plus roentgen ray | ½ encircling |
| C. S. | Radium needles, unsuccessful. Later, abdomino-perineal | ⅔ encircling |
| A. M. | Radium needles, later abdomino-perineal | ½ encircling |
| J. D. | Abdomino-perineal. Later, excision of tumor in inguinal nodes | ⅔ encircling |
| S. A. | Abdomino-perineal | 3 x 2 cm. |
| O. B. | Abdomino-perineal | ¾ encircling |
| R. B. | Radium needles | Nearly encircling |

and the other followed an heroic effort to dissect around an extensive tumor, during which the right internal iliac vessels were resected. One patient died of nephritis only nine months after his operation. The other six cases all died of persistent tumor, one committing suicide to end his suffering. One patient lived for more than four years before succumbing. None of the tumors, except the incidental one, was small. Most of them were extensive and could have been given a bad prognosis before treatment was started.

The cases treated within the last three years, and who are still alive, illustrate how the tendency has been to rely more and more upon abdomino-perineal resection. Three were treated by means of radium needles, but in two of these, operation was subsequently performed for persistence of tumor. The third has not yet been followed over two years. With one exception these tumors were fairly extensive, encircling the anus one-half or more. Following one of the abdomino-perineal operations, metastases have appeared in the inguinal nodes, which were not resected at the time of the original operation. In three of the six cases operated upon, metastases in the perirectal nodes were demonstrated. The smallest tumor in the group, three centimeters

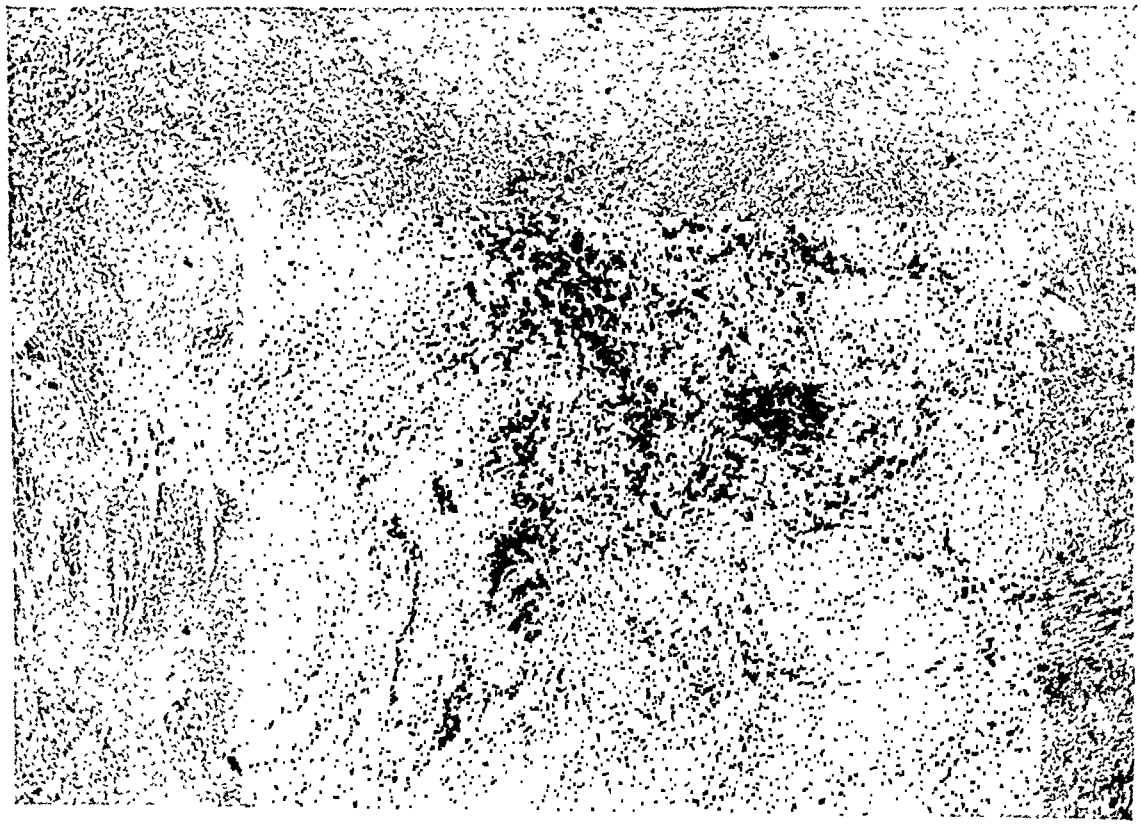


FIG. 1.—Tumor in rectal wall.

in diameter, was one that had metastasized. It is not known, of course, whether the nodes in the patient treated by radium needles are involved.

All of these patients required vigorous methods of treatment because of the extent of the lesions. In none could local excision have been logically considered as a means of cure. In the cases which proved to have involvement of the perirectal nodes, nothing but a radical operation could be expected to be successful because radiotherapy can not be relied on to eradicate tumor in the nodes. We do not know the final results of treatment, but we can show that radiation, as it was applied, had to be followed by radical surgical excision in two cases, and that an abdomino-perineal operation was followed by excision of involved inguinal nodes which had not been removed at the original operation.

One patient seems to demonstrate a point in the technic of radiotherapy.

Case 1.—Chart No. 706628: C. S., a male, age 37, had symptoms for one month, consisting of a constant desire to defecate and blood in the stools. He had a mass which distally involved the pectinate line, extended up the rectal wall for over two centimeters, and which occupied over half the circumference of the anorectal region posteriorly. Biopsy revealed squamous cell epithelioma. No inguinal nodes were found that were suspected of involvement. His general health was excellent.

He was treated interstitially with 11 radium needles, 6 cm. long, giving a total of 9,000 mg. hours. The tumor disappeared, but eight months after treatment it reappeared, extending up the rectal wall for six centimeters. An abdomino-perineal resection was then performed, with removal at the same time of some enlarged inguinal nodes. No metastases were found in these or in the pelvic nodes. It is a year from operation and the patient so far is apparently well.

A photomicrograph shows the persistent tumor as it was when removed at operation, lying in the rectal wall (Fig. 1). A section taken distal to this, in the region where the tumor presumably originally lay, shows only scar tissue where the radium needles had been placed, but no evidence of tumor (Fig. 2).

This case suggests the necessity for extending the effective field of radiation well up above the gross limits of the tumor, for the recurrent tumor in this case lay principally above the radiated field.

TABLE V

CASES SURVIVING FIVE YEARS OR MORE

| Case | | |
|---|---|---|
| G. F. | Small tumor. No metastases. Perineal proctectomy | Died 5 years, without tumor |
| M. D. | Tumor arose after radiation for pruritus | Died 12 years of tumor |
| A. R. | Perineal proctectomy. Growth encircled ½ anus. Four perirectal nodes had metastases | Alive 9 years plus |
| A. H. | Small tumor. Local excision followed by radium pack | Alive 8 years plus |
| A. R. | Small tumor. Local excision | Alive 7 years plus |
| P. A. | Growth nearly surrounded anus. Radium needles. 4651 mg. hrs | Alive 8 years |

The six cases included in Table V, out of the 37 who came originally to the hospital, include four who were alive, without evidence of tumor, followed for nine, eight, eight and seven years, one who died of heart disease but without evident tumor five years after treatment, and one who died of tumor after 12 years. The last should perhaps not be included in the series at all because her tumor arose near the anus in an area of skin which had been irradiated for treatment of pruritus. She underwent numerous procedures, none of which successfully checked the spread of the disease.

It is noteworthy that three of the remaining five cases had small tumors, approximately two centimeters in diameter. The fourth had a tumor which half encircled the anus, with metastases to four perirectal nodes. She was successfully treated by a perineal proctectomy. The fifth had a growth that nearly encircled the anus, which was a basal squamous cell type of epithelioma, and which was successfully treated by interstitial radium needles, giving a calculated dosage of 4,651 mg. hours. The method of treatment of the small tumors was simple local excision for one, perineal proctectomy for the second

(no metastases were found) and excision biopsy followed by radium pack for the third.

The last case is of interest in illustrating the factors which can enter into the choice of treatment of this disease.

**Case 2.**—Chart No. 397947: The patient was a woman, age 32, recently married, and two months pregnant, who complained of intermittent rectal bleeding for two months, and who had a papillary mass, two centimeters in diameter, in the pile-bearing area in the left posterior quadrant. Under caudal anesthesia, "resection of the mass was carried out by means of the high frequency knife. A cuff of apparently normal mucosa was left on



FIG. 2.—Scarring and ulceration, but no tumor where radium needles were inserted.

either side, and some of the underlying muscles were also removed. However, the sphincteric apparatus was in no way damaged to such an extent that incontinence might follow." The mass had previously been biopsied and squamous cell epithelioma reported. The microscopic study of the tissue excised with the high frequency knife showed the following: "The tumor has obliterated the normal architecture of the mucocutaneous junction, and is mostly located superficial to and above the internal sphincter. Superficial portions of the sphincter and the rectal muscularis have been invaded by the growth. The surface is formed of ulcerated, very vascular, thick papillary projections, lined by tumor cells and containing masses of tumor distributed irregularly throughout. . . . Epithelioma cells are found filling one small vessel deep to the main growth."

Largely on the basis of the finding of the tumor cells in the lymphatic vessel, so close to the margin of resection, the patient was advised to have a therapeutic abortion, to be followed by an abdomino-perineal resection. She had the abortion performed, but refused to be operated upon. Instead, she went to Dr. George T. Pack, at the Memorial Hospital, who "inserted a special rectal radium applicator within the anal

canal. This instrument is designed to give surface irradiation to the entire surface of the anal canal and terminal rectum. A filter of three millimeters of brass was employed and a dose of 600 milligram hours administered on each of two successive days." She had discomfort from proctitis for almost a year, but has retained full function of the bowel, has since had a child, has been free of symptoms for seven years and has no evidence of tumor, now, eight years since treatment. What part the radium played in her recovery one cannot say.

This last group of cases, five of whom appear to have been successfully treated, are the most interesting of the series. They illustrate most of all that each patient with epithelioma of the anus should be considered as a distinctly individual problem. No one form of treatment is applicable to all. The small tumor may perhaps be justifiably treated very differently from the large tumor. If the patient is intelligent enough to understand in general the risks and *sequelae* of the various forms of treatment open to him, his wishes should be the controlling factor in their choice. In retrospect, it would have been an error to have subjected patients A. H., A. R. and P. A. to radical surgery. None of the three small tumors that we encountered had metastases.

## CONCLUSIONS

1. The majority of cases of epithelioma of the anus come to the doctor too late for arrest of their disease by any known treatment.

2. For large growths, or growths with metastases, a radical resection of anus and rectum with removal of the inguinal nodes should offer the best chance of arrest. The indication for a procedure of this kind is clearest in the tumors which are neither extensive nor small, for in the former the prognosis is bad with any therapy and in the latter less mutilating measures may succeed. The perineal dissection, if undertaken, should be wide, as extension of the tumor into perirectal structures is common.

3. Radiation therapy may control growths which are locally quite extensive, but cannot be counted upon to destroy tumor deep in perirectal nodes. Metastases of this kind are frequent in tumors that involve half or more of the anus. If successful, radiotherapy has obvious advantages over treatment by radical operation. If employed, it should include in the effectively radiated field a portion of the rectal wall well above the gross upper limits of the tumor. The discomfort following radiation may for some months be extreme. Radiotherapy should usually be preceded by a temporary colostomy.

4. For small tumors, two centimeters in diameter or less, radical operative therapy, while perhaps the safest from standpoint of saving life, may be justifiably avoided. Arrest may follow local removal, radiotherapy, or a combination of the two.

5. In order that early diagnoses may not be missed, the medical profession should be aware that these tumors are found with relative frequency in people under age 40, and occur especially in relation to fistula in ano and other sources of chronic irritation about the anus.

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# CUSHING'S SYNDROME*

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IT SEEMS FITTING to discuss Cushing's syndrome in a symposium honoring the work of Dr. Allen O. Whipple, whose scholarly and inquiring spirit has placed him along with Cushing in that elect group of men whose work has made the accomplishments of American surgeons noteworthy among men of science.

After 20 years of observation, Cushing (1932) published an analysis of a group of cases exhibiting a pluriglandular syndrome which since then has often been referred to as Cushing's syndrome. While many no longer accept his concept of its pathogenesis, his description of the clinical state and his analysis of the relevant glandular interrelationship have served to establish it as a clinical entity and to extend our knowledge of endocrinology immeasurably.

## THE SYNDROME

The essential characteristics of the syndrome are, in brief: (a) painful adiposity confined to the face, neck and trunk; (b) kyphosis of the upper thoracic spine; (c) hypertrichosis of the face, neck and trunk in females and preadolescence in males; (d) dusky plethoric appearance of the skin with purplish *lineae atrophicae* on the abdomen and thighs; (e) hypertension; (f) variable backaches, abdominal pains and ultimately extreme weakness; and (g) dryness of the skin with acne and susceptibility to skin infections. Other features frequently but less consistently present were hyperglycemia, glycosuria, diminished sugar tolerance, polyphagia, polydypsia, osteoporosis, bronze pigmentation of the skin, *cutis marmorata* and purpuric ecchymoses.

Of the 12 cases reported on by Cushing, three had a small but definite basophil adenoma, two an undifferentiated adenoma and one a questionable adenoma of the hypophysis. Two had pituitary glands with normal gross appearance. Although aware of the fact that, clinically, similar syndromes had been found associated with tumors of other endocrine glands, particularly the adrenals, Cushing, nevertheless, hypothesized that the primary cause of the disturbance was a basophil adenoma of the hypophysis.

## PRIMARY CAUSES OF CUSHING'S SYNDROME

The problem of determining the primary cause of the syndrome has been beset with difficulty because no single initiating condition has been found. Cushing's original belief that a basophil adenoma was responsible is regarded as erroneous because it since has been shown that basophil adenomas are

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found unassociated with the syndrome and the syndrome is found without an associated basophil adenoma. Moreover, the cells of a basophil adenoma are nongranular and presumably nonsecretory. It has been shown that basophil cells are trophic to the thyroid and to the germ cells, both of which characteristically are depressed in their function in Cushing's syndrome (Heinbecker, 1944).

As more and more cases have been studied, it has become apparent that in persons exhibiting the syndrome, the primary cause may be (1) an adrenal cortical tumor; (2) a tumor of the ovary; or (3) a tumor of the thymus. In a group of cases without any primary tumor, it has been shown (4) that the initiating cause may be an atrophy of the paraventricular nuclei of the hypothalamus and to a lesser degree an associated atrophy of other hypothalamic nuclei, including the supra-optic and the mamillary (Heinbecker, 1944). Case 1 is cited as an example (Fig. 1).

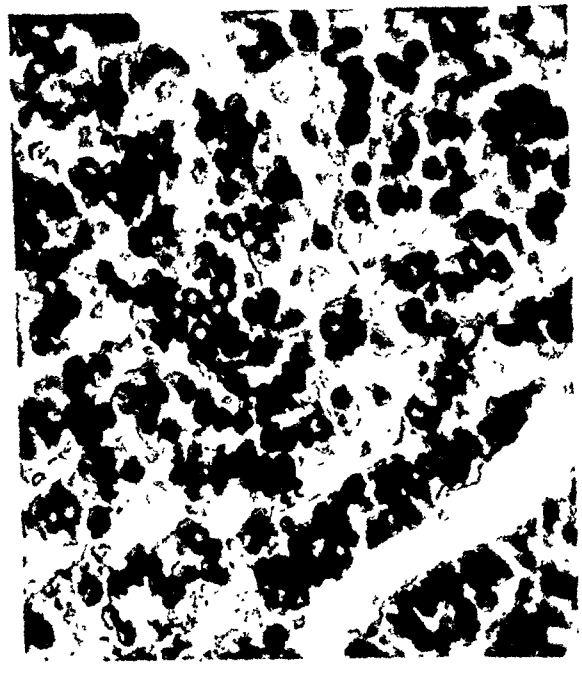


FIG. 1.—Photomicrograph (x 680) from anterior lobe of the hypophysis of a "puncture" dog showing eosinophils and chromophobes with no basophils remaining.

Crooke (1935) described a degranulation or hyalinization of the basophil cells of the hypophysis in persons exhibiting Cushing's syndrome. This finding, confirmed by others, including Rasmussen (1936), may be regarded as present in all true examples of the syndrome. The problem of pathogenesis resolves itself into determining how the various primary causes above listed may lead to degranulation or hyalinization of the basophil cells of the hypophysis.

## EXPERIMENTAL AND CLINICAL INVESTIGATIONS

Heinbecker (1944) reported that in "puncture" dogs in which the neural hypophysis was denervated through the oral approach by a puncture wound separating it from the supra-optic and paraventricular nuclei, there occurred a loss of basophil cells in the glandular hypophysis (Fig. 2). The eosinophil cells thereby became dominant. Such a change is complete within a year. The actual time-interval necessary for complete disappearance of the basophil cells has not been determined. Partial granulation may still be present in cells three months after making the lesion. By comparing the histology of the other endocrine glands of a dog without basophil cells with those in a totally hypophysectomized dog, it is possible to determine the target organs of the eosinophil and the basophil cells. Such studies have shown that the eosinophil cells are trophic to the adrenal gland, to the prostate, to the inter-

stitial cells of the testis and to the corpus luteum. The basophil cells are trophic to the thyroid gland, to the ovarian follicle and they are essential for the maturation of the germ cells.

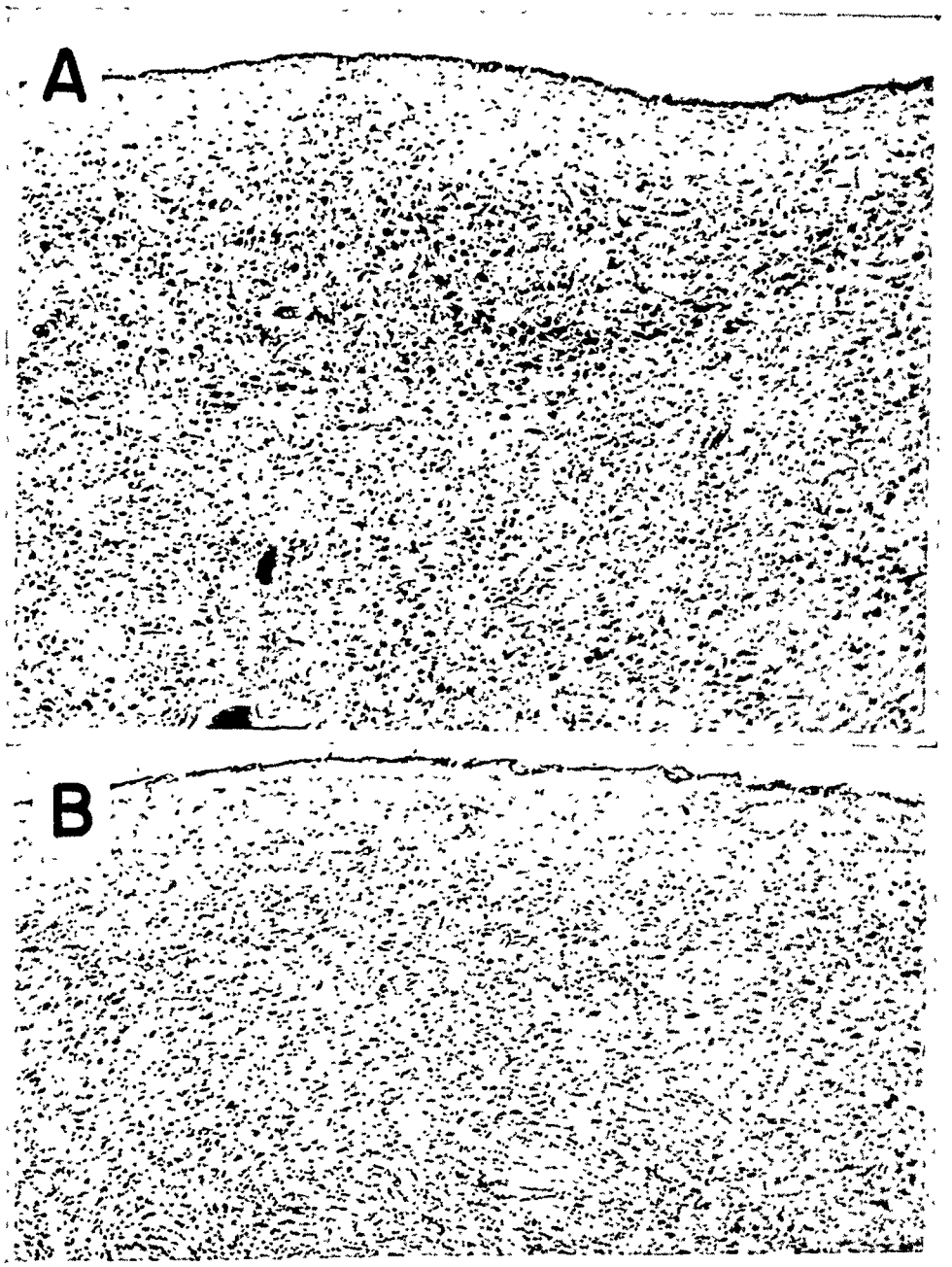



FIG. 2.—(A) Photomicrograph of paraventricular nucleus (x 45) of normal brain, female, age 40.
(B) Paraventricular nucleus (x 45) from Case 1. Note marked loss of cells as compared with the normal.

In other experiments in the dog, lesions were made caudal to the stalk to interrupt fibers coming from or going to the paired paraventricular nuclei. In such dogs it was found that no retrograde degeneration occurred in the

cells of the paraventricular nuclei but the animals nevertheless became obese and lost most of the basophil cells in the glandular hypophysis. Those cells which remained have few granules. The inference is drawn that fibers reaching the paraventricular nucleus from more caudal parts of the nervous system are afferent and excitatory. Their interruption results in a depression of function of the paraventricular nucleus.

In man exhibiting Cushing's syndrome, degranulation of the basophil cells is not complete; it is only partial, and has been described by some as an hyalinization. In the "puncture" dog the change in the cytology of the glandular hypophysis is more pronounced and is attributed to a more marked depression of the secretion of the neural hypophysis, or it may be a species difference. It seems logical that if it could be shown that the hormones of the tumors, which have been regarded as primary causes of Cushing's syndrome, result in a depression of the action of the neural hypophysis by neutralization of its secretion, a similar cytologic change in the glandular hypophysis should be effected.

Adequate evidence is available to establish that desoxycorticosterone is an antagonist of the hormone of the neural hypophysis. When given to dogs in fairly large dosage, a state indistinguishable from *diabetes insipidus* results (Ragan, *et al.*, 1940; Mulinos, *et al.*, 1941). It appears reasonable to assume that hormonally active tumors of the adrenal cortex causing the signs and symptoms of Cushing's syndrome secrete sufficient desoxycorticosterone or desoxycorticosterone-like substance to neutralize the secretion of the neural hypophysis, whereby degranulation or hyalinization of the basophils would be effected. In fact, evidence of a rise in serum sodium and a depression of serum phosphorus has been reported (McQuarrie, *et al.*, 1937) and offers supporting evidence for the above assumption. Such depression of the basophil cells would be associated with a dominance of the eosinophil cells, actual or relative (Heinbecker, 1944, *loc. cit.*). Recently Mellgren (1945) has made counts of the cells of the hypophysis in a case of Cushing's syndrome due to an adrenal tumor. He demonstrated an increase in the eosinophil cell count over the average normal control count.

The similarity of chemical structure of desoxycorticosterone and progesterone is established. Likewise, it has been shown that in the pregnant albino rat, the survival time after adrenalectomy was prolonged during pregnancy in spite of the fact that in every case abortion or resorption of the foetuses occurred (McKeown and Spurrell, 1940). The life-maintaining effect of crystalline progesterone has been demonstrated in adrenalectomized ferrets by Gaunt and Hays (1938). The ability of progesterone to neutralize, *in vitro*, the action of posterior pituitary extract on the estrogen primed uterine muscle has been demonstrated by Reynolds and Allen (1935). On the basis of such evidence one might expect a tumor of the ovary with the capacity to secrete progesterone or progesterone-like substances to bring about hyalinization of the basophil cells of the glandular hypophysis by neutralizing the effect of the hormone of the neural hypophysis. Such a case with the clinical and pathologic

findings characteristic of Cushing's syndrome, including polyuria and hyalinization of the basophil cells, has been reported by Norris (1938). In this instance a tumor of the ovary was proven to be the primary cause. It was not established by actual test that the secretion of the tumor was progesterone. However, it is known that large amounts of estrogenic substances do depress the eosinophil cells and do not bring about a depression of the hypophysial basophil cells (Zondek, 1941). It also has been observed in this clinic that a large tumor of the adrenal cortex, bringing about only marked androgenic effects, did not cause any of the signs and symptoms characteristic of Cushing's syndrome (Case 2). It is assumed, therefore, that the changes in the hypophysis characteristic of Cushing's syndrome are not produced by the androgens. By a process of exclusion it is assumed that the hormone secreted by the tumor in the case reported by Norris must have been progesterone or a progesterone-like substance, and that when secreted in large amounts this substance can neutralize the secretion of the neural hypophysis.

The other primary cause of Cushing's syndrome, a tumor of the thymus, presents in the present state of our knowledge greater difficulties of proof. No evidence as to the nature of the hormone of such a tumor is available. Analysis of the clinical record of two such cases (Leyton, Turnbull and Bratton, 1931) shows, however, that polyuria was present in both and Crooke demonstrated hyalinization of the basophil cells in each (1935, *loc. cit.*). Because of the existence of polyuria it seems reasonable to assume that the hormone of the thymic tumor itself or indirectly through overaction of the adrenal cortex was one capable of causing neutralization of the hormone of the neural hypophysis. Obesity was observed also, indicating an overbalanced function of the adrenals, to which the eosinophil cells of the hypophysis are trophic. In both instances definite hypertrophy of the adrenals was demonstrated at autopsy.

The above experimental and clinical evidence, while not complete, is regarded as adequate to support strongly the concept of the pathogenesis of Cushing's syndrome submitted. It would seem to harmonize heretofore conflicting data. It is suggested that either because of a decrease of the secretion of the neural hypophysis, because of hypofunction of the hypothalamic nuclei which control its secretion, or through excess secretion of a neutralizing hormone from a tumor of the adrenal cortex, of the ovary, or of the thymus, a change in the cytology of the glandular hypophysis is effected which results in a dominance of the eosinophil-adrenal cortical hormone complex over the basophil-thyroid hormone complex. Changes in other endocrine glands follow as a result of depression of the neural hypophysis and of cellular balance in the glandular hypophysis.

### CORRELATION OF EXPERIMENTAL WITH CLINICAL DATA

In those instances of Cushing's syndrome where the primary lesion is an atrophy of the cells of the supra-optic and paraventricular nuclei, the polyuria can be explained with adequate experimental support as the result of a depre-

sion of the secretion of the neural hypophysis secondary to the depression of these nuclei (Heinbecker and White, 1941). When the primary cause is an adrenal cortical, ovarian or thymic tumor the supra-optic and paraventricular nuclei have been found cytologically normal and presumably are then functionally active. Polyuria then would be the result of a neutralization of the hormone of the neural hypophysis by the hormonally active secretion of the particular tumor concerned. The experimental evidence to support this interpretation is favorable but incomplete where a thymus or ovarian tumor is the primary cause.

The obesity which is always present is regarded as secondary to an increased appetite and also to an alteration in the metabolism of the body whereby fat is formed and stored excessively, a consequence of the overbalanced activity of the adrenal cortical-eosinophil hormone complex, secondary to diminished function of the neural hypophysis. Under such circumstances, marked obesity has been observed in the dog (Heinbecker, White and Rolf, 1944).

The decrease in sugar tolerance which is altered and which may be sufficient to warrant a diagnosis of *diabetes mellitus* may also be attributed in part to the overbalanced action of the eosinophil-adrenal cortical hormone complex. Support for this interpretation has been given by the recent evidence of Price, Cori and Colowick (1945) that anterior pituitary extract inhibits the utilization of glucose by animal tissues, an inhibition which is counteracted by insulin. In the puncture dog lacking the hormone of the neural hypophysis and with eosinophil cell dominance, insulin insensitivity has been demonstrated (Heinbecker and Rolf, unpublished data). It has been shown previously that insulin sensitivity is due to a decrease in eosinophil cell function (Heinbecker and Rolf, 1944). The dog apparently does not react to diabetogenic influences to the same degree as does man. A diabetogenic influence of the adrenal cortical hormone has been established by Long, *et al.* (1940). Clinical experience supports the concept that the development of obesity and of generalized arteriosclerosis tend to precipitate the state of diabetes mellitus.

Persons exhibiting Cushing's syndrome develop diastolic hypertension and arteriolar sclerosis, the mechanism of which is being investigated. Observation in this laboratory on the control of renal blood flow in dogs by a hormone of the eosinophil cells of the glandular hypophysis working in combination with the adrenal cortical hormone (Heinbecker, Rolf and White, unpublished data), together with other observations concerning glandular interrelationships in general has led to the following concept of the pathogenesis of hypertension in Cushing's syndrome, evidence in support of which will be presented in detail elsewhere.

In brief, it is held that the neural hypophysis is activated or inhibited by other portions of the nervous system. A decrease of the secretion of the neural hypophysis results in a dominance of the eosinophil cells and a decrease or degranulation of the basophil cells of the glandular hypophysis. The eosinophil cells are trophic to the adrenal gland, the basophil cells to the thyroid gland. A neutralization of the secretion of the neural hypophysis by desoxycor-

ticosterone, by renin, or by progesterone has a similar effect on the cytology of the glandular hypophysis as does a decrease in the secretion of the neural hypophysis. The action of such a mechanism offers an explanation as to how the glandular hypophysis can be modified by the nervous system *via* the neural hypophysis *without any direct nervous connection.* A depression of the secretion of the neural hypophysis or its neutralization by other hormones results in a sensitization of the blood vessels to epinephrine, to renin, and to the desoxycorticosterone eosinophil complex. Diastolic hypertension results from the action of epinephrine, or renin and of the desoxycorticosterone-eosinophil complex in narrowing extrarenal blood vessels in the sensitized animal. The factors responsible for the functional narrowing of the blood vessels also serve as dominant factors in producing the changes characteristic of arteriolar sclerosis. To them can be added the effect of the hypertension itself and a decrease in the thyroid-basophil hormone complex.

Investigations previously reported showed that in persons with Cushing's syndrome content of calcium salts in the vessel walls becomes markedly increased while the skeleton becomes decalcified. A similar tendency is exhibited in many persons with advancing age and with arteriosclerosis. No definite evidence implicating abnormal function of the parathyroid glands in the altered disturbance of calcium salts has been observed clinically. Experimental evidence that the parathyroids are under the trophic influence of the hypophysis rests on the demonstration by some of a decrease in serum calcium after the administration of anterior lobe hormone. However, the results of other investigations of this subject have been negative. The impression has been gained in this laboratory that under experimental conditions in the dog where there is a marked increase in the basophil cells and a decrease in the eosinophil cells of the hypophysis, the parathyroid glands become enlarged. This would lead to the suspicion that in Cushing's syndrome the function of the parathyroid glands might be decreased rather than increased. At present, the experimental evidence is inadequate to explain the decalcification of the skeleton observed in the syndrome other than that it is associated with the development of the generalized arteriosclerosis.

The changes observed in genital function are readily harmonized with the experimental data. The depression of the basophil cells would lead to a depression of the ovarian follicles in the female and thus to a decrease in menstruation. In the male it would lead to a depression of the maturation of the spermatids. The overaction of the eosinophil-adrenal cortical hormone complex should lead to some increase in the excretion of the ketosteroids in the urine.

DISCUSSION.—The pathogenesis of Cushing's syndrome is outlined in terms of endocrine imbalances precipitated by disturbances of function of the central nervous system or by the excessive secretion of tumors with endocrine function. It is realized that these endocrine imbalances produce in certain individuals signs such as the dusky plethoric moon-face which distinguish the syndrome, and that somewhat similar imbalances do not produce them in other individuals. It seems desirable therefore to postulate that in the indi-

viduals who respond with the true syndrome there exist one or more constitutional factors in the blood vessels and possibly in other tissues which condition their response. Of their nature, nothing yet is known.

## SUMMARY

A concept of the pathogenesis of Cushing's syndrome is presented.

Four causes of the syndrome are regarded as being primary, a tumor of the adrenal cortex, a tumor of the ovary, a tumor of the thymus, or an atrophy or inhibition of the hypothalamic nuclei, particularly the paraventricular and the supra-optic.

Experimental evidence is reviewed to indicate how these four primary causes depress the function of the neural hypophysis and effect a dominance of the eosinophil-adrenal cortical hormone complex over the basophil-thyroid hormone complex. Reference is made to the changes which result in other endocrine glands.

The extent to which such alterations in function of the hypophysis explain certain of the clinical signs and symptoms of the syndrome is indicated.

## CASE REPORTS

**Case 1.**—White, married female, age 33; well until five years before admission to Barnes Hospital, when she began to notice increased hair growth on face, blurring of vision and slight ankle edema. During the five years of illness she periodically experienced polyphagia and polyuria. For two years before admission she suffered from ulcers on her legs. Her skin became dry and scaly; she developed stiffness and weakness of her muscles. Frontal headaches and drowsiness were present for two years. For the past year she did not menstruate. During the six months prior to her death her face became full and rounded; her complexion florid. In five years her weight increased from 160 to 208 pounds. Purple striae appeared over the lower abdomen and thighs. Physical examination on admission revealed a patient with an appearance typical of Cushing's syndrome. She had hypertension 200/140; a diminished sugar tolerance; basal metabolic rate –22; daily urine output varied from two to five liters, N.P.N., 35 mg. per cent.

The patient's chief reason for being in the hospital was to have the ulcerations on her legs treated. The ulcers became infected and the infection spread widely beneath the skin and muscles. A streptococcal septicemia finally caused her death.

The essential autopsy findings were: hyalinization of the cytoplasm of the basophil cells of the pituitary; basophilic invasion of the posterior lobe of pituitary; increased pigmentation of the inner zone of the cortex of adrenal; obesity of trunk and face; hirsutism; striae of skin of abdomen and right thigh; unhealed infected amputation wound of left knee; draining wounds of left shoulder (abscess drained 13 days ago); healed wounds of right lower leg (recurrent ulcers); edema of subcutaneous tissue of right lower leg; ecchymosis with superficial bullae of skin of the left flank; edema and congestion of lungs; congestion of liver; focal fatty degeneration of liver; local fatty degeneration of kidneys; hyperplasia of spleen; atrophy of pancreas (45 grams): hyperostosis of bones of skull; focal necrosis with intranuclear inclusion bodies in adrenal and liver; simple cyst of the ovary (10 x 10 x 8 cm.). No pituitary adenoma was present.

Serially cut sections, 20 and eight mm. in thickness, through the pre-optic and hypothalamic regions, stained with cresyl violet, revealed marked loss and atrophy of the nerve cells in the various nuclei of this region. These changes were particularly striking in the supra-optic and the paraventricular nuclei. The ependymal lining cells of the third

ventricle showed a similar atrophy. Round cell infiltration was lacking. While the blood vessels showed intimal thickening and vacuolization of the endothelial lining cells, such changes were not specific for these regions. Sections were taken at random from the thalamus and brain-stem, and even when they showed vessel changes showed no nuclear atrophy similar to that seen in the hypothalamus.

**Case 2.**—Colored female, age 19, entered Barnes Hospital because of marked hairiness of face and body of three years' duration, and amenorrhea.

Menstruation began at age of 17, was always scant, but regular for about one year, then stopped. Urine output and appetite normal. Examination on admission showed the patient to have a marked growth of hair on the face and over the body generally. She was not obese. Blood pressure 110/60; the fasting blood sugar was 71 mg. per cent, sugar tolerance curve normal. Basal metabolic rate +14, −1, +3. Blood cholesterol 87 mg. per cent; blood sodium 346 mg. per cent; blood potassium 19.1 mg. per cent; blood sodium chloride 634 mg. per cent. A right adrenal tumor was diagnosed with the aid of intravenous pyelography. The urine contained 8–10 times the normal amount of 17 ketosteroids (Dr. Willard Allen).

A tumor of the right adrenal gland the size of a large grapefruit was removed successfully after preoperative preparation with liberal amounts of adrenal cortical extract. After operation, the patient again required large amounts of whole adrenal cortical extract for several weeks to prevent collapse and hyperpyrexia. Her ultimate recovery was complete. Microscopic study of the tumor tissue showed it to be an adenoma of the adrenal cortex, few mitotic figures being present. For two years the patient has been well. Her menstruation is normal; blood pressure normal.

COMMENT: This patient did not show any of the signs and symptoms characteristic of Cushing's syndrome. The nature of the hormone secreted by the tumor was primarily androgenic; nevertheless, it must also have contained other factors necessary for life because of the large amount of whole adrenal cortical hormone indispensable after the operation for two weeks. Because the tumor did not produce polyuria and hypertension it apparently did not secrete an excess of the desoxycorticosterone fraction. The normal basal metabolic rate and the low blood cholesterol indicate further than the hormone did lead to changes in the glandular hypophysis characteristic of Cushing's syndrome.

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# ACUTE INTUSSUSCEPTION IN INFANTS AND CHILDREN

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ACUTE INTUSSUSCEPTION is the most important and one of the most serious surgical emergencies met with in infancy and early childhood. It has been called variously invagination, introsusception and intussusception, and as the name implies, consists of invagination of a segment of bowel into a distal contiguous segment. The former is known as the intussusceptum and the latter as the intussuscipiens.

The frequency of the disease as seen in The Babies Hospital during the past 19 years has been about one in every 300 admissions. The 123 cases reported in this series have, with one exception, been seen and treated by the attending and resident staff of The Babies Hospital during the years 1927 to 1945, inclusive.

Since the last series reported from this hospital by Bolling,[1] in 1923, the mortality rate has declined from 30 per cent to the present 13 per cent. This is encouraging progress, which seems to have been achieved by better treatment following hospitalization, because the duration of the disease before admission to the hospital has shown no appreciable decrease. It is unfortunate that a disorder with such clear-cut symptoms and physical findings should continue to be so belatedly recognized. That the time to hospitalization can be effectively reduced was shown by Clubbe[2] in the early part of this century, when he attained an average duration of 17 hours in a fairly large series by means of an intensive educational campaign directed at both the medical and nonmedical group. That this is true is further demonstrated by the fact that among the private patients in this group the average duration was 18 hours to hospitalization, compared to 33 hours for the ward cases. The complete lack of improvement in early recognition of this emergency condition in this community during the past years would imply that considerable benefit might be obtained by an effort to bring it more vividly to the attention of the medical public as well as the lay group, through "Well" Baby Clinics and Health Clinics.

No obvious cause for intussusception could be found in 83 per cent of the cases; in 11 per cent enlarged lymph nodes were described in the region of the ileocecal junction, and in the remaining 6 per cent the figures were made up roughly as follows: Meckel's diverticulum was found in four cases; cysts were found in three; and a polypus in one. The definite organic causes were divided equally between the age-groups below one year, and over one year.

The classification used in this report is that suggested by Clubbe,[2] and followed by Bolling[1]—(1) ileo-ileal, or enteric; (2) enterocolic, or the double type; (3) ileocecal; and (4) colic. Eighty-five per cent of the cases in this group were of the ileocecal type.

In considering the natural history of the disease it was found that the white and colored races were equally represented, according to hospital admissions; males predominated over females in the ratio of 1.9 to 1; 44 per cent of the children were wholly breast fed and almost all of them were taking solid food by the time they were four months old. Three patients in this series had a history of intussusception in immediate or closely related members of the family. Forty-five per cent of the cases occurred in the first child and an additional 20 per cent in the second child. The usual description of a healthy, well-developed infant was borne out by the finding that most patients fell within a normal weight limit for age and height. Characteristically, these children are healthy and have little which might be considered significant in their past history. In this series there were, however, 11 with a history of recent or fairly recent diarrhea, four with history of previous intussusception, and five with a history of allergy.

The outstanding features of the histories were: Acute onset, intermittent pain, vomiting, and a bloody bowel movement following the onset of the illness. It might be well to point out, however, that 20 per cent of the patients had perfectly normal bowel movements after the symptoms began. The most frequently noted physical findings were: Good nutrition and hydration, a palpable abdominal mass, and blood on rectal examination. About 30 per cent of the patients had increased temperatures and white counts above normal, although, in general, this information was not of much value except in the cases of marked elevations, when it was considered to be a poor prognostic sign.

In ten cases in which the barium enema was used as a diagnostic aid, it was positive, and in an additional case of the ileo-ileal type, abnormality in the region of the terminal ileum was suggested.

The average duration before admission for this group was 33 hours, and 44 per cent were seen within the first day of illness. It is discouraging to note that there has been no improvement in these figures when five-year groups are compared over the period studied. Twenty-five per cent of all children had been ill three days or longer; this is hard to understand when one considers that the patients are drawn from a large metropolitan population within easy reach of doctors and hospitals.

The age distribution placed 75 per cent of the cases in the ages three to 11 months, with one case less than one month old and three cases over four years of age. As noted previously, the yearly rate has been fairly constant and there has been no noticeable seasonal variation in incidence.

Because of the uncertainties attendant upon nonoperative treatment by carefully controlled barium enema and fluoroscopy, this method has been rarely used. In all, five patients were so treated; in one there was complete reduction and uneventful recovery took place; of the remaining four, in one there was failure within limits of what was considered safe pressure, and one promptly recurred with evacuation of the barium. The two remaining patients were operated upon because of some uncertainty as to the completeness of the reduction. One was found to have an ileo-ileal intussusception in the terminal

ileum, while the other was found to have been completely reduced by the barium. There were three instances of spontaneous reduction, one following an enema, and two following an anesthetic. One of the latter was operated upon and evidences of the intussusception were found. All three made uneventful recoveries.

In two nonoperative cases the diagnosis was made at autopsy; both of these were very young infants who were admitted to the hospital in poor condition, and one showed on postmortem an ileo-ileal intussusception, and the other a double jejunojejunal intussusception.

The increasing appreciation of the value of parenteral fluids and blood in the preoperative preparation of such cases is well-illustrated in this series. In fact, it seems to be the one addition to treatment which might be considered accountable for the diminution in the mortality rate. During the years 1927–1931 one-fifth of the patients received some form of preoperative fluid therapy, and the mortality rate was 20 per cent, whereas during the years 1941 to 1945 the mortality rate fell to 10 per cent, and almost half of the patients received preoperative supportive fluids. Postoperative therapy of this type has always been at a somewhat higher level, though it, too, has increased. The impression gained, however, is that in many instances it was too little, and too late. Too much importance cannot be attached to this form of therapy. All such cases should be brought into adequate fluid and blood volume status before, during and after the acute surgical phase of their treatment.

Another form of preoperative therapy which has been minimally used in this group is that of gastric or duodenal suction. Gastric lavage should always be done and continuous gastric suction instituted if distention exists.

The striking drop in mortality rate in acute intestinal obstruction in adults following the adequate use of these forms of therapy is well-known, and they should certainly not be neglected in such cases in children.

The operative technic has not changed much during the period studied, ether being the anesthesia of choice, and a paramedian right rectus muscle-splitting incision the one customarily employed. The intussusception is then gently reduced by milking from below, and the characteristic dimple and edema in the area of the cecum ironed-out by the use of hot packs and gentle pressure before the intestine is replaced into the abdomen. A layer-closure of the abdomen is always done, and the suture material most frequently used is chromic catgut, with usually two or three heavy silk retention sutures. Appendicectomy was performed in 13 cases; in three the appendix was found to be abnormal on pathologic examination. Generally speaking, appendicectomy is considered unwise unless, of course, the appendix appears grossly to be involved.

Nine cases required resection because of irreducibility, gangrene or perforation. In five of these, anastomosis was effected by the suture method, and in four by a Mikulicz procedure. In the cases done by suture there were three deaths and one survival under one year of age, and in the cases done by the Mikulicz procedure there were two deaths and two survivals under one year

of age. It would appear from this limited experience that there might be some virtue in the employment of the Mikulicz procedure, particularly in very young patients.[3, 4]

The postoperative course of the uncomplicated case is usually uneventful, though they may have a sharp temperature rise during the first two or three days, perhaps due to absorption of toxic products from the injured bowel. Feeding is usually not a problem, and the foul diarrhea mentioned by some authors[4] has not been noted in this group. The postoperative complications most frequently noted were shock, pneumonia, disruption, and obstruction.

Confirming the findings of others, 83 per cent of the cases showed no visible reason for the development of intussusception. The most frequently noted accompanying pathology was enlarged mesenteric lymph nodes. This finding was also noted by Wakeley and Atkinson,[5] and as a possible evidence of generalized lymphatic hyperplasia, would seem to lend credence to the theory that lymphatic hypertrophy in the region of the terminal ileum and ileocecal valve is an important etiologic factor in these cases. Six per cent of the cases showed some definite organic abnormality which was considered to be a precipitating factor; these were listed previously. Again, coinciding with the experience of others, 85 per cent of the cases were of the ileocecal type, 12 per cent of the enterocolic or double type, and 3 per cent of the entirely enteric variety. No instance was recorded in this series of a colocolic intussusception.

Wound-healing complications, as recorded, included four disruptions, with no fatalities, three trivial wound infections, and two serious wound infections, with one fatality.

There were 16 deaths, or an over-all mortality rate of 13 per cent. The average duration of the disease in these cases before hospitalization was three days, and over. The major causes of death are listed in the following order: shock, peritonitis, and pneumonia. In one death, which occurred in the operating room, the intussusception was complicated by a volvulus of the entire small intestine. Another death occurred on the 49th day, with recurrence of intussusception following an apparently successful resection. Two nonoperative deaths occurred in young infants who were admitted to the hospital in poor condition and with rather obscure histories; one of these cases was found at autopsy to have a double jejunojejunal intussusception, and the other an ileoileal intussusception. While the enteric and enterocolic types of intussusception constituted only 15 per cent of the group, the mortality rate in cases of this type was 55 per cent. The mortality rate tended to be higher in all types as the intussusception progressed toward the rectum.

There were two cases of what might be considered chronic intussusception, one of four weeks' duration and one of one week's duration. The diagnosis of partial intestinal obstruction was made roentgenologically, and confirmed at operation. Both were successfully reduced and made uneventful recoveries.

There were four cases of recurrent intussusception; with one exception the time to first recurrence was less than one year. One case recurred three times in nine years, and another twice in five years. These cases were all of

the ileocecal type, and no cause was found to account for the recurrent intussusception. In three cases, side-to-side suture of the portion of the terminal ileum to the ascending colon was done, twice on the occasion of the first recurrence. One of these cases subsequently had two recurrences, the other was apparently cured. The third case was so treated on the second recurrence, and had no further trouble. The fourth case received no preventive treatment, and has remained well. Though no conclusions can be drawn from this experience, in general, it is felt that preventive measures are of no avail.

There appear to be two main factors influencing the mortality rate in this condition; first, the duration of the disease; and second, the type of intussusception. The mortality rate in those cases seen in the first 24 hours was less than 2 per cent, whereas in those ill three days or longer it was 72 per cent. As noted previously, the enteric and the enterocolic type of intussusception, while comprising only 15 per cent of the total, carried a mortality rate of 55 per cent. Physical findings of poor prognostic import, and probably related to the above factors, were poor hydration, distention and elevated temperature. As noted previously, the mortality rate tended to increase in all types of intussusception as the intussusception progressed toward the rectum. The greater hazard inherent in the enteric and enterocolic types of intussusception is brought out further by figures indicating that resection was necessary in 21 per cent of these cases, and in only 4 per cent of the ileocecal type.

Sixty-one per cent of these cases have been followed in the clinic for an average of three years. Two of the group have small postoperative herniae, and two have symptoms which might be considered related to the disease, namely, repeated attacks of colic, and severe constipation.

## SUMMARY AND CONCLUSIONS

(1) Figures relating to the natural history, signs, symptoms and pathology of this condition as reported by other authors[4, 5, 6] have, in general, been confirmed.

(2) Factors of poor prognostic significance in this series were found to be duration over 24 hours; the enteric, or enterocolic type; advanced progress toward the rectum of the intussusceptum; poor hydration; bowel distention; and elevated temperature.

(3) The time before hospitalization has not changed since the last series reported from this hospital 23 years ago. A plea is made for earlier recognition of this surgical emergency.

(4) It is concluded that the safest and surest treatment is surgical, although the experience with insufflation methods under fluoroscopic control has been limited.

(5) Fluid balance and blood volume should be restored and maintained during the preoperative and operative period by parenteral means, and continued during the postoperative course, as indicated. A more liberal use of such measures is urged.

(6) All cases should receive a gastric lavage preoperatively, and if abdom-

inal distention exists, continuous gastric or duodenal suction should be instituted.

(7) Nine cases of resection are reported, with a mortality of 55 per cent. It is suggested that a Mikulicz procedure may be of value in reducing the mortality, particularly in young infants.

(8) Follow-up data are given on 61 per cent of the cases followed for an average of three years.

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# PREVENTION OF WOUND INFECTION BY THE INJECTION OF NONTOXIC ANTIBACTERIAL SUBSTANCES*

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IN A PREVIOUS PAPER,[1] a mixture of streptomycin, 200 units per cc., and sulfamylon, 5 per cent,† was demonstrated as being capable of killing a three-hour growth of bacteria on a blood agar plate. This combination destroyed a large variety of bacteria and mixed cultures. In fact, no resistant strains have been encountered thus far. All of the gram-negative bacteria were destroyed although *B. pyocyaneus* tended to grow back again over the area where the pseudomonas was previously destroyed.

This combination of streptomycin and sulfamylon was also demonstrated to be innocuous to tissues. When constantly in contact with adult tissue, cultures were only mildly inhibited in growth. The mixture did not produce hyperemia of the conjunctiva of the eye of the rabbit nor adhesions in the peritoneal cavity. When injected into muscle, neither leukocytosis nor fibrosis resulted. It did not retard the rate of wound healing.

This data suggested that the mixture of streptomycin and sulfamylon at these concentrations should be an ideal subcutaneous antiseptic. Thirty clinical cases were treated with the combination without untoward effects and without infection, but this group was too small to be of statistical significance. To prove the point that the combination would prevent infection in wounds, the experiments about to be described were undertaken. A method was previously devised in experimental animals of producing 100 per cent infected wounds. The failure of treatment of the resulting infection with other agents has been reported elsewhere.[2] This same method has now been employed to test the efficiency of the combination of streptomycin, 200 units per cc., and sulfamylon, 5 per cent, in preventing infection in the wound.

*Method.*—Under anesthesia, a defect 3 cm. square was cut in the skin of the back of the rabbit just lateral to the spinal column. The loose subcutaneous tissue and fascia were excised and the underlying muscle was vigorously crushed with a Kocher clamp. The wound was then contaminated with bacteria, either using floor dirt as the contaminant, or a 24-hour growth of a specific bacteria. Without débriding the crushed tissue, the wound was then treated with the combination of streptomycin and sulfamylon. The surface was washed with the combination and, in addition, 15 to 20 cc. were injected in the tissues about the wound. The wound was covered with vaselined gauze and a protective dressing and jacket applied to the animal. The control group of wounds received no treatment. They were covered with dry gauze.

* The work described in this paper was done under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and Columbia University, New York, N. Y.

† Marfanil = homosulfanilamide = 4-amino, 2 methylbenzene sulfonamide hydrochloride. Merck furnished the streptomycin, Winthrop the sulfamylon.

The first group of animals was treated with streptomycin and sulfamylon immediately after the wound was made and contaminated. The second group was treated three hours after the wound was made and contaminated, and the third group was treated after an interval of 12 hours.

The wounds were inspected four days later to determine whether infection had occurred. A cotton swab was saturated with secretions from the wound and this was smeared on a blood agar plate and incubated for 24 hours to

TABLE I

| Rabbit No. | Contaminated With | Treatment | Gross Appearance After 4 Days | Blood Plate Culture on 4th Day |
|---|---|---|---|---|
| | | UNTREATED CONTROLS | | |
| 640 | Floor dirt | None | Grossly infected | Good growth of bacteria |
| 642 | *Staph.* culture | None | Wound very dry and necrotic | Thick culture of *Staph.* |
| 644 | *Staph.* culture | None. Vaselined gauze | Wound full of pus | Thick culture |
| 648 | Floor dirt | None. Vaselined gauze | Wound full of exudate | Good growth of bacteria |
| 660 | Floor dirt | None. Vaselined gauze | Wound full of dead tissue and pus | Good growth of bacteria |
| | | TREATED SERIES | | |
| 641 | Floor dirt | Immediate treatment with streptomycin mixture | Wound quite clean | No growth |
| 643 | *Staph.* culture | Immediate treatment with streptomycin mixture | Tissues, in general, healthy. Good healing obtained later | Scattered colonies |
| 649 | Floor dirt | Immediate treatment with streptomycin mixture | Clear bloody exudate. Edematous connective tissue | Two or three colonies |
| 650 | Floor dirt | Immediate treatment with streptomycin mixture | Wound clean and moist | No growth |
| 659 | Floor dirt | Immediate treatment with streptomycin mixture | Healthy and red, with some dead tissue | One colony |
| | | DELAYED TREATMENT | | |
| 645 | *Staph.* culture | 3 hrs. after trauma with streptomycin mixture | Considerable pus | Good growth of bacteria |
| 646 | *Staph.* culture | 3 hrs. after trauma with streptomycin mixture | A little pus and dead white tissue | Thickly scattered colonies, 200+ |
| 647 | Floor dirt | 3 hrs. after trauma with streptomycin mixture | Dead tissue and pus under skin edges | Good growth of bacteria |
| 656 | Floor dirt | 24 hrs. after trauma débrided and treated with streptomycin mixture | No gross pus | No growth |
| 651 | Floor dirt | 4 hrs. after trauma débrided and treated with streptomycin mixture | No gross pus | One colony |

determine the quantity of bacterial contamination. A direct smear was also made and this was given a Gram stain. Color photographs were taken of the wound to record the character of the healing. The amount of exudate and the appearance of the tissues were noted. The rate of healing was not studied.

Both the wounds which became infected and those that did not were subsequently treated with the combination of antibacterials to determine whether a more rapid resolution of the established localized infection occurred and if continuing protection took place.

*Results.*—The five wounds treated immediately with the mixture of sulfa-

mylon and streptomycin remained free of infection on the fourth day, while the five wounds that were not treated were filled with pus (Table I). The blood plates made from the nontreated wounds showed heavy concentrations of bacteria (Fig. 1). On the contrary, those made from the treated wounds showed only occasional colonies of bacteria or no growth (Figs. 2 and 3). The tissues of the nontreated wounds were gray and necrotic and appeared frankly infected (Fig. 4). The tissues of the treated wounds showed no infection. They were bright red and the crushed tissue had disappeared (Fig. 5). A small amount of clear fluid was present. Granulations were absent, as is usually the case in this specie of animals in this particular anatomic location. Direct smears taken from both groups of wounds showed the following contrasts: In those taken from the wounds which became infected, every leukocyte contained many bacteria and there were many extracellular micro-organisms as well. In the smears taken from the treated wounds wherein infection was prevented, numerous leukocytes were also present but only an occasional one contained bacteria, and none were extracellular.

Additional treatment of both the infected and the noninfected wounds with the antibacterials yielded the following results. Neither injection nor washing caused resolution of infection although the bacteria remained susceptible to the action of the streptomycin and sulfamylon. To the contrary, wounds in which infection had been prevented remained uninfected regardless of whether the subsequent treatment was with the combination of antibacterial substances or with vaselined gauze or with dry dressing. The tissues in these wounds continued to be bright red. Rapid contracture of the surrounding tissues and regeneration of new tissues subsequently took place. In other words, when infection was originally prevented, the wound continued to heal without evidence of infection while if the wound became infected, antibacterial substances did not cause resolution even though the bacteria remained susceptible to the antibacterial agent. Figure 6 shows that the wound in which infection was prevented was almost healed on the 15th day. Figure 7 shows that contraction also took place in the infected wound although pus and slough were still present eight days later. Figure 8 shows a bacterial smear taken two hours after treatment with the combination of antibacterial substances. Many bacteria are still present in spite of treatment with the potent antibacterial mixture.

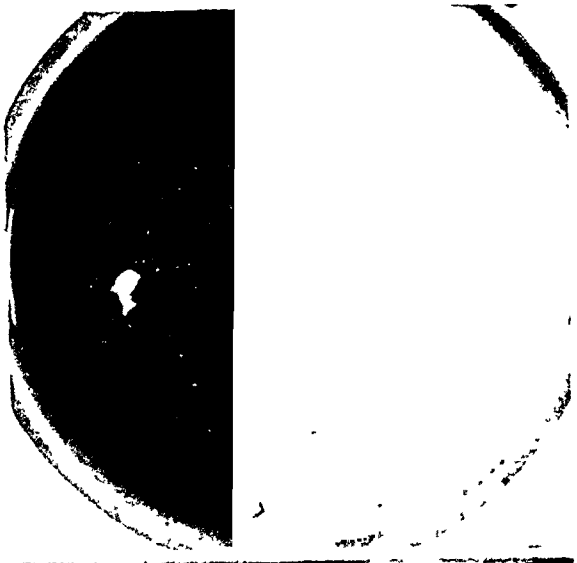
In contrast to the success obtained in preventing infection of wounds in the presence of crushed tissue by immediate treatment with the combination of streptomycin and sulfamylon, infection occurred when wounds were treated three hours after infliction and contamination. One wound appeared to be reasonably free of infection, yet it contained considerable fluid and the blood plate showed a large number of bacterial colonies. The other four wounds were definitely infected and their blood plates were characteristic. The recovered bacteria remained susceptible to the combination of antibacterials and, hence, an increased resistance to the action of the mixture would not account for the failure to prevent infection. As was expected, blood smears taken from the wounds, three hours after contamination, showed that there were really fewer

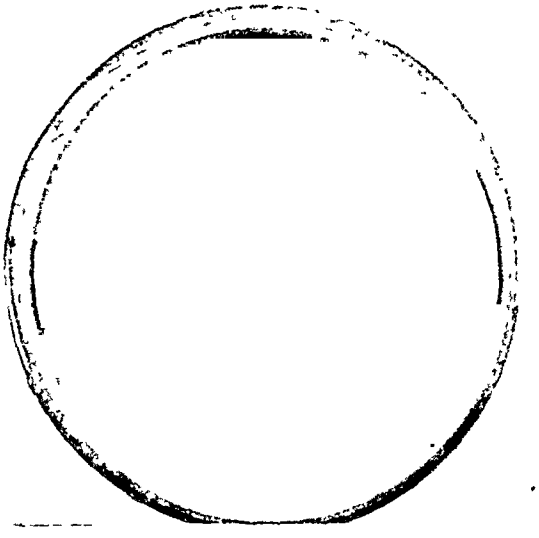
bacteria on the surface of the wound than when it was first contaminated. An abundance of the mixture was used to wash the tissues and was injected and, therefore, the presence of too many bacteria did not seem to be a logical explanation of the lack of success in controlling infection. In an attempt to find an

FIG. 1



FIG. 2





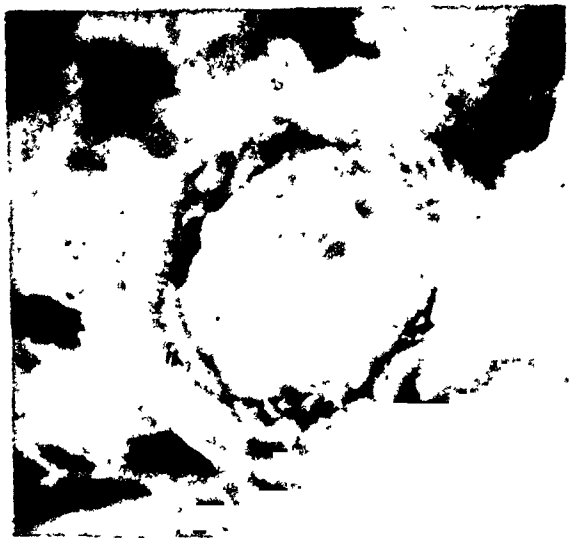


FIG. 3

FIG. 4

FIG. 1.—Blood plate—infected wound.
FIG. 2.—Blood plate—treated wound.
FIG. 3.—Blood plate—treated wound.
FIG. 4.—Gross appearance—infected wound, 4 days.

explanation, biopsies were taken of the loose connective tissues directly under the skin and of the muscle. Microscopic examination showed that many leukocytes had already invaded the tissues and every leukocyte contained many bacteria.

The combination of streptomycin and sulfamylon also failed to prevent infection from developing when treatment was given 12 hours after infliction

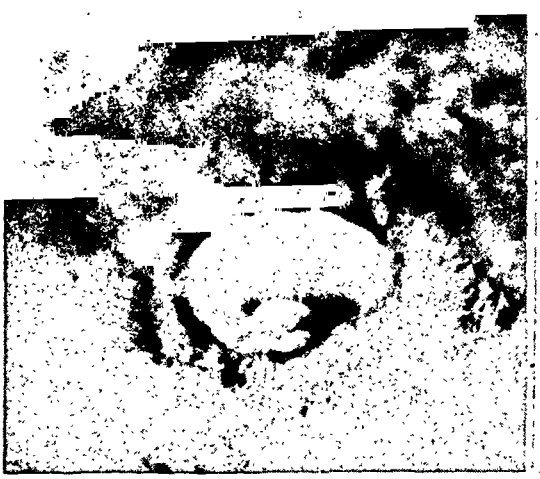
and contamination of the wound. Again, the bacteria remained susceptible to the action of the combination, although now there was a definite increase in their numbers and, again, examination of the tissues showed that there were many leukocytes present which contained bacteria. Moreover, some of the bacteria were extracellular.

FIG. 5



FIG. 6





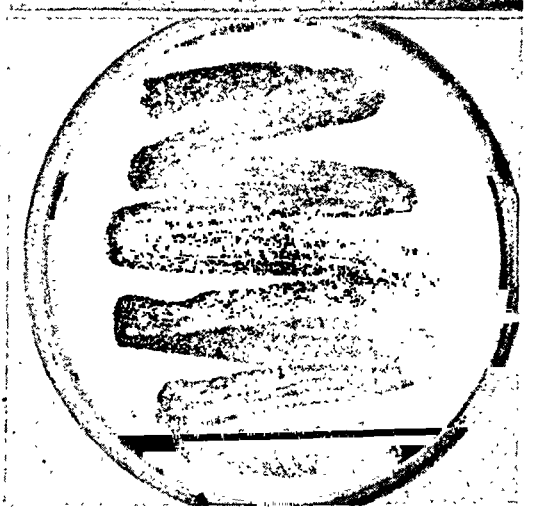


FIG. 7

FIG. 8

FIG. 5.—Gross appearance—treated wound, 4 days.
FIG. 6.—Treated wound—15th day.
FIG. 7.—Nontreated wound—8th day.
FIG. 8.—Blood plate—infected wound, 2 hours after treatment.

One of the three-hour wounds and one of the 12-hour wounds were treated by débridement and irrigation and were injected with the combination of streptomycin and sulfamylon. Infection was prevented in both wounds.

DISCUSSION.—Without a pronounced increase in the number of bacteria in the wound, with the bacteria remaining susceptible *in vitro* to the action of the antibacterials and with the amount of traumatized tissue unchanged, some other

reason must be found to explain why infection was not prevented when the wound was treated three hours after injury.

There is the possibility that the micro-organisms had located deeper in the tissues. Failure of prevention of infection has often been explained on the basis that bacteria deep in tissues are not contacted by solutions washing the surface of the wound, and, for this reason, the method of injecting the solution was originally adopted, apparently with success, immediately after injury. Lack of prevention later is difficult to explain on the same basis, therefore, if the bacteria remained extracellular. Only one other possible explanation can be offered; namely, that the extracellular fluid clotted and with the deposition of fibrin the diffusion of the antibacterial solution was prevented throughout the area. Dilution of the concentration of streptomycin and sulfamylon by edema fluid does not seem to be the answer because an excessive amount of solution was used.

The most logical explanation of the failure to prevent infection of the wound after three hours is, that many of the bacteria were no longer extracellular, and the antibacterial substances failed to contact them. Phagocytosis of the bacteria by the leukocytes placed the micro-organisms within cells. Both Wright[3] and Flemming[4] showed that ingestion by leukocytes does not always destroy bacteria. They made cultures from pus obtained from wounds and demonstrated that their contained bacteria grew on the surface of smeared blood plates. On the other hand, "sterile" leukocytes recovered from the pleural cavity in response to aleuranot, contained an antibacterial substance which prevented the growth of bacteria smeared on blood plates.

Thus, while phagocytosis is helpful in combatting infection, yet, if the leukocyte is killed before the bacteria are destroyed the micro-organisms are free to contaminate the wound again. Flemming believes, for example, that leukocytes, wandering to the surface of wounds, die and undoubtedly leukocytes are killed in many ways during the exudative phase of healing. If, therefore, destruction of bacteria by the leukocytes can not be relied upon and antibacterial substances must be used to kill them, then the leukocytes must be penetrated by the solution. If the leukocyte is dead, this is difficult to accomplish and the leukocytes will be killed unless the substance has a special selective action against the micro-organism.

The three-hour period was selected at random. Consequently, no statement can be made as to whether the combination of antibacterial substances would fail if used within this interval. On the other hand, failure certainly continues after three hours, for phagocytosis continues and new difficulties are added. The number of bacteria increase after four or five hours and they invade tissues and cause putrefactive necrosis. This necrotic tissue not only shields the bacteria from the action of the antibacterial substance, but also provides ready nutrition for those surviving. On the other hand, a wound free of dead tissue is not fertile soil for the remaining micro-organisms to propagate again. From the experimental viewpoint, it is perhaps fortunate that one element of the problem can be studied as early as three hours after injury.

The failure of streptomycin and sulfamylon to hasten the resolution of the established infection recalls that penicillin and the sulfonamides, although they did prevent spread of infection from the wound, also failed, regardless of whether they were used locally or generally. The sulfonamides failed partly because they were only bacteriostatic, acted slowly and, like penicillin, did not inhibit the growth of gram-negative bacilli that are also capable of producing pus. Inadequacy of antibacterial action cannot be used as an excuse for the failure of the combination of streptomycin and sulfamylon however, and, hence, the contention is strengthened, that resolution of an established infection requires in addition to a potent bacteriocide, adjunct chemotherapy; to dissolve slough, to explode leukocytes, and to provide chemical drainage. This need has been discussed elsewhere.[5]

While streptomycin and sulfamylon, applied immediately, were used to prevent infection in these experiments, other antibacterial substances can be substituted if they possess the required properties which allows them to be injected. These are, that the substance will kill bacteria in the presence of blood and serum in a bacteriocidal concentration that will not destroy tissues nor cause exudation. In addition, the substance must possess a wide range of bacteriocidal activity, act quickly, and be free of general toxicity. Penicillin, for example, can be substituted as an antibacterial to destroy gram-positive cocci and bacilli, but another one would have to be used with it to destroy the gram-negative bacilli. Some of the new antibiotics now being developed will undoubtedly qualify.

No attempt has been made to employ either streptomycin or sulfamylon alone. They were combined originally with the thought that their antibacterial activity would complement each other. If either one were used alone, sulfamylon 5 per cent seems the most likely one to select because streptomycin has weak action against the green and hemolytic streptococci and sulfamylon has proven effectiveness against anaerobic bacteria.

A word of caution must be said about the clinical use of these antibacterials to prevent infection in wounds. They, and the method of employment, must not be substituted for good surgery. Although infection was prevented by immediate treatment in the presence of traumatized tissue in the experimental wounds, dead tissue is a powerful member of the trio which produces infection in wounds and should be removed as completely as possible because no evidence was produced that the mixture would prevent infection caused by contaminated foreign bodies left in the presence of dead tissue. Foreign bodies as the second member of the trio which produces infection should always be removed. On the other hand, the experiments do demonstrate that these antibacterials will prevent infection when some traumatized tissue is present and, therefore, when complete removal of traumatized tissue is not always possible, the use of this combination adds a measure of security which cannot be omitted. Further, the use of this combination to prevent infection in contaminated wounds containing a minimal amount of traumatized tissue and foreign bodies should be invaluable, for example, to wash the clean contaminated

operative wound, made to remove the diseased appendix, or for a large bowel resection. The line of anastomosis can be swabbed repeatedly with the solution without fear of creating adhesions.[1] Its use for first-aid, to cleanse small traumatic wounds, not containing either foreign bodies or dead tissue, can certainly be highly recommended for immediate treatment in place of so-called "antiseptics" that usually destroy tissues as well.

The problems of extending the usefulness of the mixture of streptomycin and sulfamylon in preventing infection beyond the three-hour period is now being studied.

## CONCLUSIONS

(1) Sulfamylon, 5 per cent, and streptomycin, 200 units per cc., prevented infection in crushed wounds of five rabbits. All five control wounds became infected. No attempt was made to débride the excessive amount of traumatized tissue present. The wounds were washed and the surrounding tissues were injected with 20 cc. of the combination of antibacterial substances. The treatment was carried out immediately after infliction and contamination of the wound.

(2) On the other hand, the combination of sulfamylon and streptomycin failed to prevent infection in five experimental wounds treated three hours after infliction and contamination of the wound.

(3) The inclusion of the bacteria within leukocytes is offered as a possible explanation for the protection of the bacteria against the action of the antibacterials after three hours. *In vitro* tests showed that they were still susceptible to the action of the antibacterial substances. Failing to penetrate to the bacteria within the leukocyte, the cell may subsequently die and liberate them unharmed to recontaminate the wound.

(4) Repeated injections and washing of the wound with an established localized infection did not hasten resolution of the process of suppuration although the bacteria were susceptible to the *in vitro* action of the mixture. Pus in these wounds also contains bacteria with leukocytes where they would not be contacted.

(5) If this combination of antibacterial substances is used clinically to prevent infection in wounds, the principles of good surgery should not be neglected. Use should be limited to contaminated wounds, relatively free of traumatized tissue and foreign bodies.

(6) Other antibacterials can be substituted for the sulfamylon and streptomycin to prevent infection by immediate treatment if they kill bacteria quickly in the presence of blood, have a wide range of activity, do not destroy or irritate tissue at the bactericidal concentration and are nontoxic.

(7) Injection of antiseptic substances locally points to new possibilities in the local treatment of wounds.

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# A STUDY IN ARTICULAR REPLACEMENT

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THE PROBLEM of degenerative disease in articulations, either weight-bearing or not, is one which still challenges the surgeon. How to alleviate the pain and how to restore to use a painful stiff joint, due to degenerative disease, are questions which as yet have not been answered. It is not so simple as replacing caries in teeth, although some may consider that there is a rough parallelism. It is not simply a matter of prosthesis either, nor can it be simple substitution. Although the replacement idea is attractive so far it has not been adequately developed. Fundamentally, the idea may be seen as sound if the dynamic interrelationship between the host site and the replacement donor material were understood and, within useful limits, controlled.

The substitution for a degenerating articular surface of fascia and other soft-tissue materials cannot be compared to that of the cup arthroplasties[1] because the fascial replacement is temporary and the degree of survival of the donor tissue cannot be controlled. Conversely, though the arthroplastic cup is nonabsorbable it maintains an ever-shifting relationship to the host tissue, and cannot be considered to be a replacement but rather a substitution for the articular surface. The union, so to speak, of the donor to the host never takes place. In the fascial arthroplasties there is early death of the donor tissue; where the nonabsorbable cup is used the relationship of the donor element, particularly toward the head, is unstable.[2] The idea that with movement of the donor cup no single area of the host bone is subjected to sufficient strain to cause local death, is extremely attractive but clinical application of the idea has shown it to be only partially and temporarily successful. Perhaps if the cup moved in the hip socket and was fixed to the neck a more stable equilibrium of the joint could be established.

An experiment was planned to study a situation in which the weight-bearing strain of the donor element of the joint sought and reached a stable equilibrium with the host tissue of the moving part. The donor part was of course mobile on the torso element of the joint.

Perhaps for this experiment vitallium may have been a more suitable material.[3] However, chrome nickel steel alloy was used because it had been employed previously in the problem of open reduction and fixation of fractures.[4] Fixation of the donor element was considered from the point of view that: (a) Maximum weight-bearing surface be attained in the host tissue; (b) some limited adaptability of position to the host tissue should be present; (c) minimum injury to the circulatory supply of the host tissue be inflicted; and (d) the motor forces controlling the joint be maintained in normal dynamic balance insofar as possible.

The flanged nail fixation was adopted. It was seated into the medullary canal to control torque and transverse stress but a maximum surface was used for the weight-bearing plateau. For reasons of experimental expediency, the dog's shoulder joint seemed most suitable. As a weight-bearing joint it was accessible without great trauma to the soft-part attachments. The same cannot be said for the hip joint in the dog.

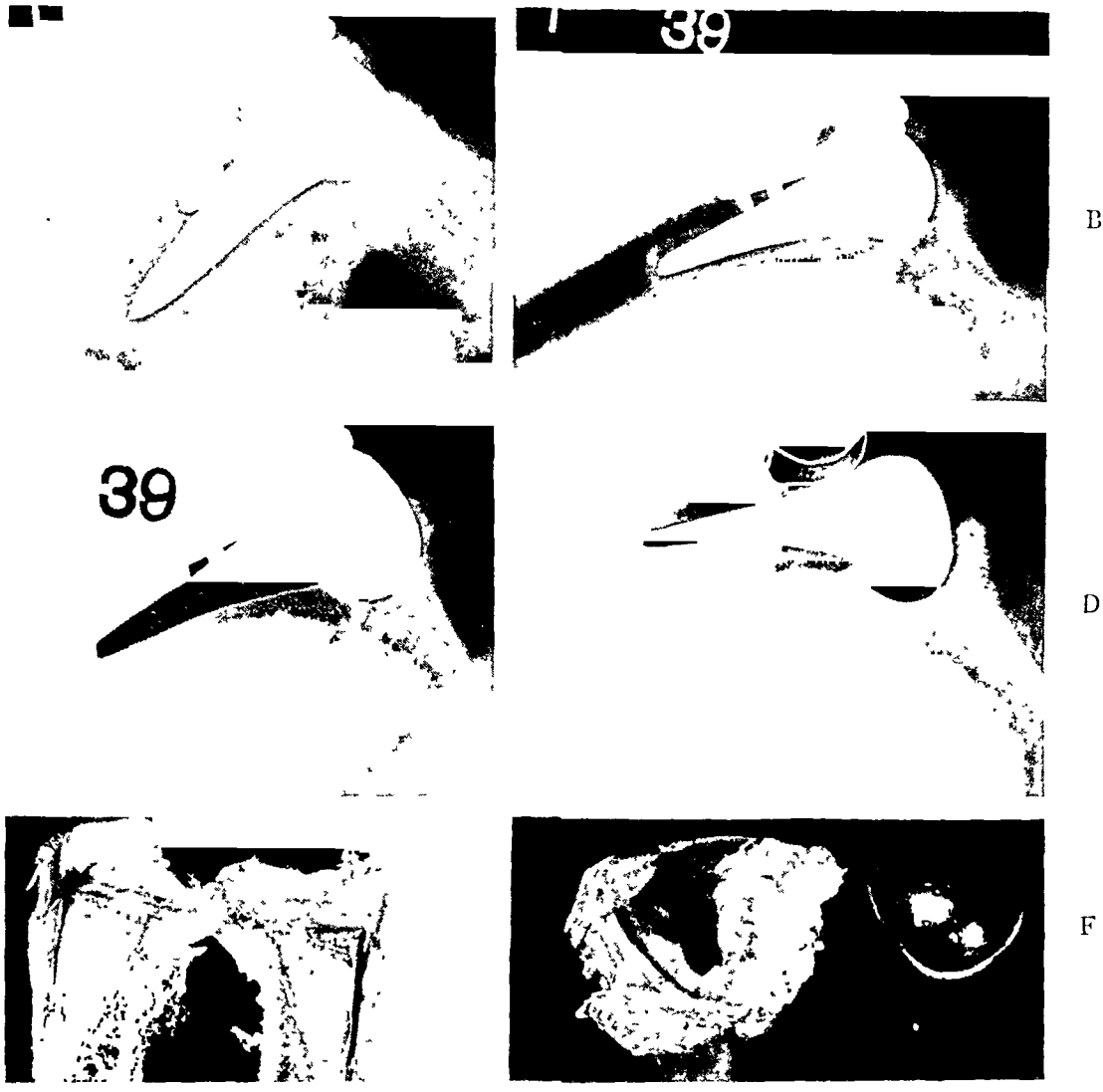



FIG. 1.—Roentgenograms of four shoulders five to ten months postoperative. The gross specimen of one of these, No. 15789 is shown after removal; five years and eight months postoperative.

A series of six dogs was employed. When certain technical difficulties were overcome, it was found that the animals, after operation, regained function to a limited degree in four weeks and thereafter progressed satisfactorily. By three months, almost full use was attained. There remained a residual limitation of motion depending on the technical success of the operation and other minor factors. The weight of the animal did not appear to be an important factor.

The first animal, though successful surgically, died of postoperative pneumonia. One of the others in which the greater tuberosity was not removed but in which a transcapsular approach was used, dislocated when the external rotator cuff pulled out the sutures and had to be sacrificed. The other four

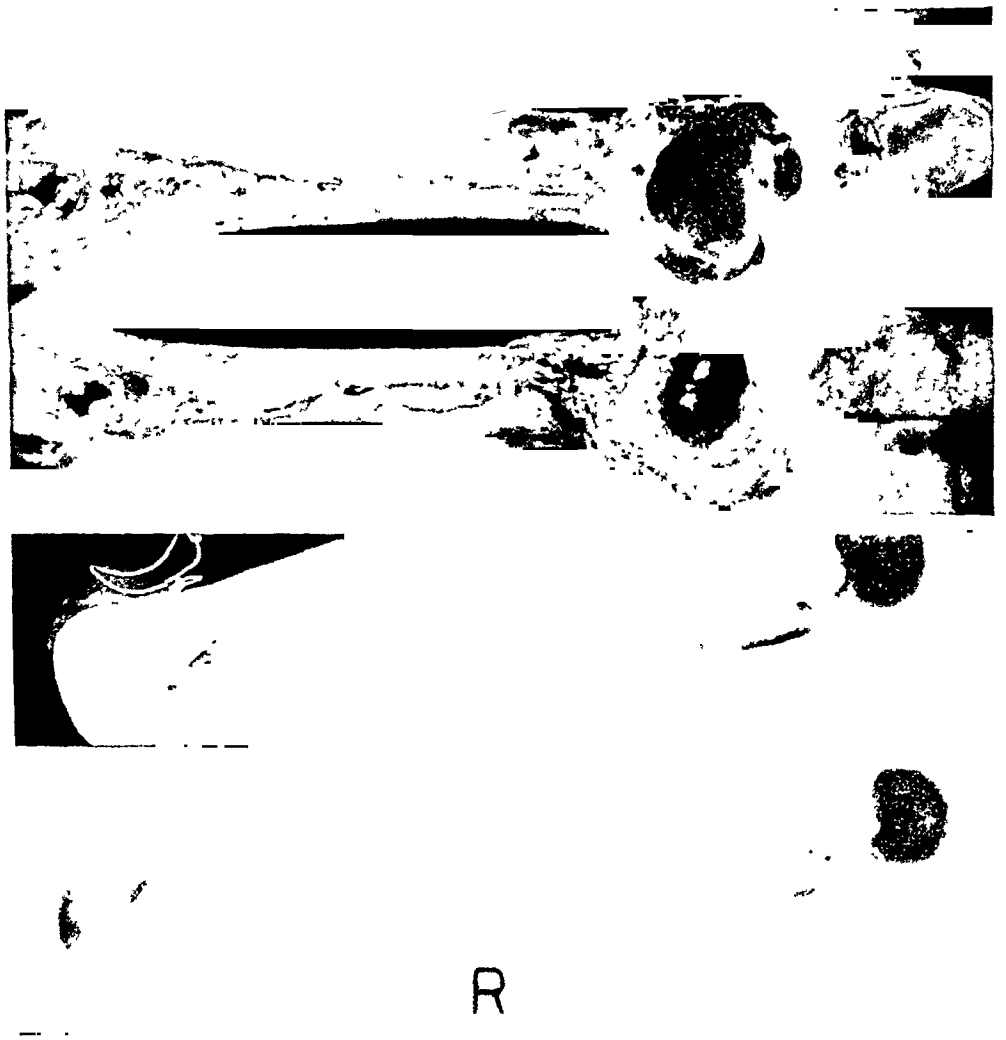



FIG. 2.—The operated and unoperated humerus and glenoid five years and eight months postoperative.

animals are referred to in Figure 1, upper roentgenograms. Three animals survived the operation well over six months. All the animals were active within four days of the operation. Except for one (Figure 1, upper left) they attained full activity in three months. Even the animal which developed osteomyelitis was active and bearing weight in three months, but it was obvious by comparison with the others that there was pain and limitation of use. When it was clear that the surgical procedure was feasible and accomplished the intended purpose of attaining function with a humeral head which had been replaced, the animals except the five-year survival were sacrificed. This latter animal is reported in the following protocol:

## EXPERIMENTAL

*Protocol of Dog.*—Number 15789: Black and white male hound, weighing 39 pounds, somewhat underweight because he was convalescing from distemper. Operated June 6, 1940. Dr. Frank Nobiletti assisting.

For application of the replacement element to the right shoulder under nembutal anesthesia, the right shoulder was explored. The skin was separated-off with towels. The anterior margin of the deltoid was detached and the muscle retracted posteriorly. Some of the upper limits of the pectoral and subscapularis muscle attachments were separated to allow access to the upper humeral shaft. The external rotator cuff was detached with the greater tuberosity and retracted. A step-cut block of the upper humeral shaft was carried with the greater tuberosity to make anatomic reattachment of the greater tuberosity simpler.

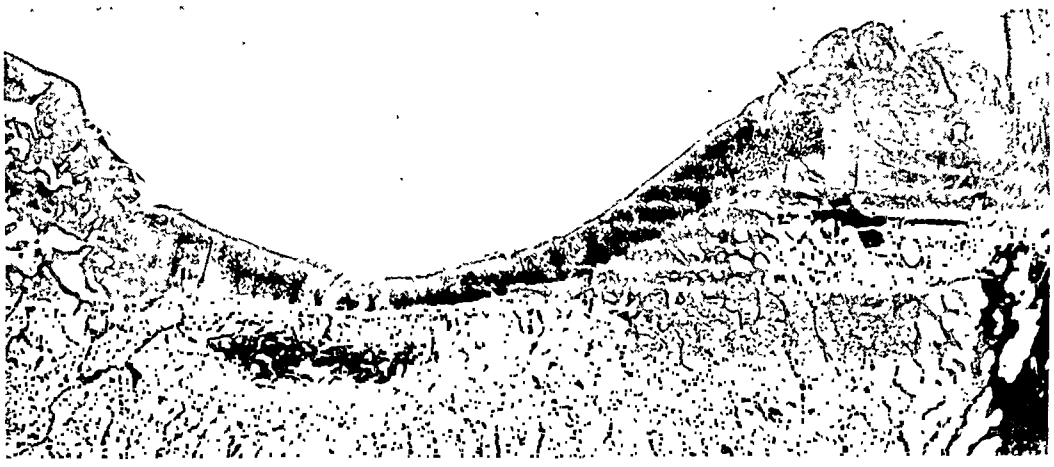


FIG. 3.—A low power field of the glenoid cavity.

The humeral head was then excised at the anatomic neck intracapsularly where the head meets the slightly expanded upper portion of the shaft. There remained a plateau of fairly dense cancellous bone. This plateau was marked with the flanged nail and the channel for the nail portion was partially formed with the use of a thin narrow osteotome. The donor element was then seated firmly into place and the shoulder was reduced.

The greater tuberosity was replaced and sutured through small drill holes with a mattress of No. .010-inch high chrome, low nickel wire.

The conjoint cuff and capsule were repaired and the wound was closed in anatomic layers. The skin was closed with vertical mattress sutures of "c" silk. Hemostasis was adequate but not absolute.

*Postoperative Course.*—The 1st postoperative day was eased by the use of morphine. The animal was quiet and ate very little. The wound showed considerable edema. By 48 hours, though still having pain, the animal was more comfortable. His appetite was fair, and the wound appeared clean. By the 4th postoperative day the dog had become livelier, touching his foot to the ground. His condition remained good, and by the 10th postoperative day the wound was healed and he was hopping around actively on three legs.

There was no essential change until the 30th postoperative day, when it was noted that the animal was bearing weight on the operated leg occasionally. He appeared in excellent health and ten days later was found consistently bearing weight on all four extremities. Forty-eight days postoperatively, although there was considerable atrophy of the shoulder girdle muscles, the dog was in excellent spirits bearing full weight and quite active. Indoor movies were taken of his activity.

By three months postoperatively, to an unprejudiced observer, the animal was completely normal. Careful clinical examination revealed, however, that there was some residual atrophy and, motion in all planes was reduced about 10 per cent. Outdoor movies taken at this time showed a normal running gait, and the dog could be made to jump from a four foot wall. This he did repeatedly, landing on his fore paws without appearing to favor the operated extremity.

A year later, except for a slight prominence of the greater tuberosity masked by his pelt, it was impossible to tell by the dog's activity that he had been operated upon. The atrophy had completely disappeared. He became a laboratory pet. About this time



FIG. 4.—A higher power of the articular surface of the glenoid cavity shown in Figure 3.

(August, 1941) the author joined the armed forces and the care and observation fell to the animal operating room supervisor, Miss Daisy Mapes, who performed her duties superbly. The animal was mated to a suitable laboratory companion, but this concession to his welfare and happiness seemed ill advised because after long celibacy this unaccustomed activity almost prostrated the poor beast.

Nevertheless, he continued in good condition. Upon the author's return to civil duties (October, 1945), the dog was carefully examined both with and without anesthesia. This examination was five years and four months after the replacement in the right shoulder. Clinically, the dog was doing well. He had gained weight and his coat was thick. He

ran and chased without impediment. Close examination revealed that the limitation of motion had increased although this could not be detected by watching the animal's activity.

Forward extension of the shoulder as compared with its fellow was reduced about 20 per cent. External and internal rotation were reduced about 50 per cent. Caudal flexion of the shoulder was reduced about 25 per cent. There was a fine crepitation present on forced passive movement, which apparently was not painful. There were clinical indications that a degenerative arthritis was present. A roentgenogram, taken on November 29, 1945, showed that although the joint space was clear, there was evidence of periarticular proliferation.

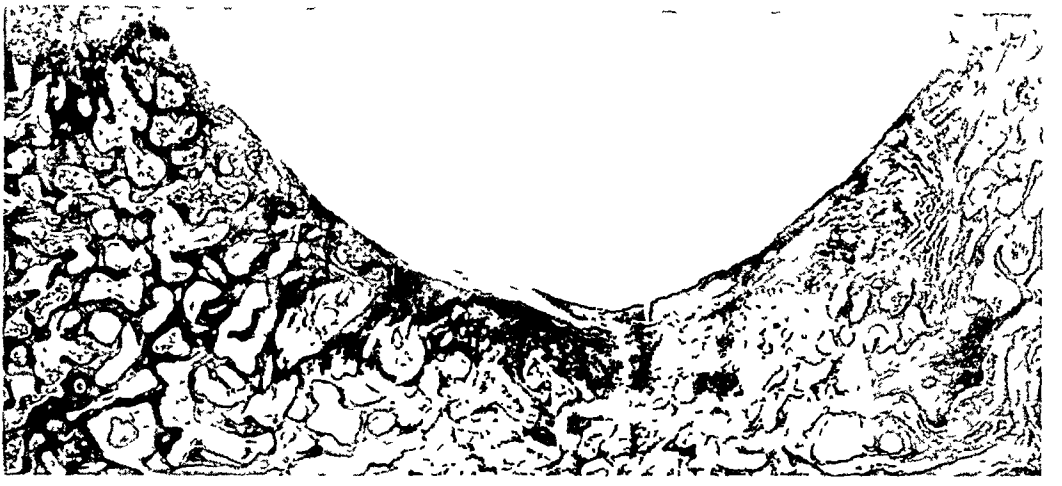


FIG. 5.—A low power field of the adaptive tissue near the greater tuberosity

*Postmortem Examination.*—January 7, 1946: *Gross:* Condition of the muscles was good. There was no atrophy of the deltoid or trapezius. The infraspinatus was slightly atrophied. The insertion of the subscapularis muscle had migrated slightly distally. There was some heaping-up of the margins of the groove of the long biceps tendon but the binding down of the tendon and the lessening of mobility was slight. The tendon body appeared slightly flattened where it passed over the smooth metallic humeral head, otherwise not abnormal. The joint capsule, as a whole, was thickened and there was a small amount of synovial fluid present, which appeared normal.

On entering the joint the donor element appeared smooth, shiny, and uncorroded The glenoid cartilage did not appear so smooth, as on the normal side. There was some lipping of the glenoid margin in the upper half with almost none in the lower margin. The hypertrophic tissue of the glenoid margins made the glenoid appear slightly deeper than on the normal side. There was some synovial membrane thickening, less in the inferior portion than elsewhere. The greater tuberosity was considerably hypertrophied and had partly overgrown the lateral part of the metallic element. This hypertrophy was enough so that abduction and rotation were limited because the greater tuberosity almost impinged on the tip of the spinous process of the scapula.

*Adaptation of the Humerus.*—The replacement element was smooth and very firmly seated in the humerus. The overgrowth by the greater tuberosity and firm seating in the humerus made removal of the prosthesis difficult. When removed, the adapted part of the humeral shaft showed a smooth, glistening fibrous membrane such as one sees beneath the surface of a stainless steel plate well-applied to bone. Beneath the fibrous membrane, there appeared a smoothly adapted layer of bone, no longer cancellous but appearing now to be of homogeneous density. There was noe spot of discoloration. This was a region about three millimeters in diameter where the three-flanged nail element meets the weight-bearing part of the head (Fig. 1, gross specimen).

TEXT DESCRIPTION OF FIGURES

Fig. 1.—(Upper left) shows roentgenograms of dog No. 15321, taken five months and ten days postoperatively. The operation was unsuccessful. The animal developed an osteomyelitis.

Fig. 1.—(Upper right) shows roentgenograms of dog No. 15329, taken five months and eight days postoperatively. Clinically, there was full use.

Fig. 1.—(Middle left) shows roentgenograms of dog No. 15328, taken five months and eight days postoperatively. The donor element is adapted. The animal was completely active but clinical examination showed considerable limitation of motion. The latter two animals had for fixation of the greater tuberosity, a small four screw plate.

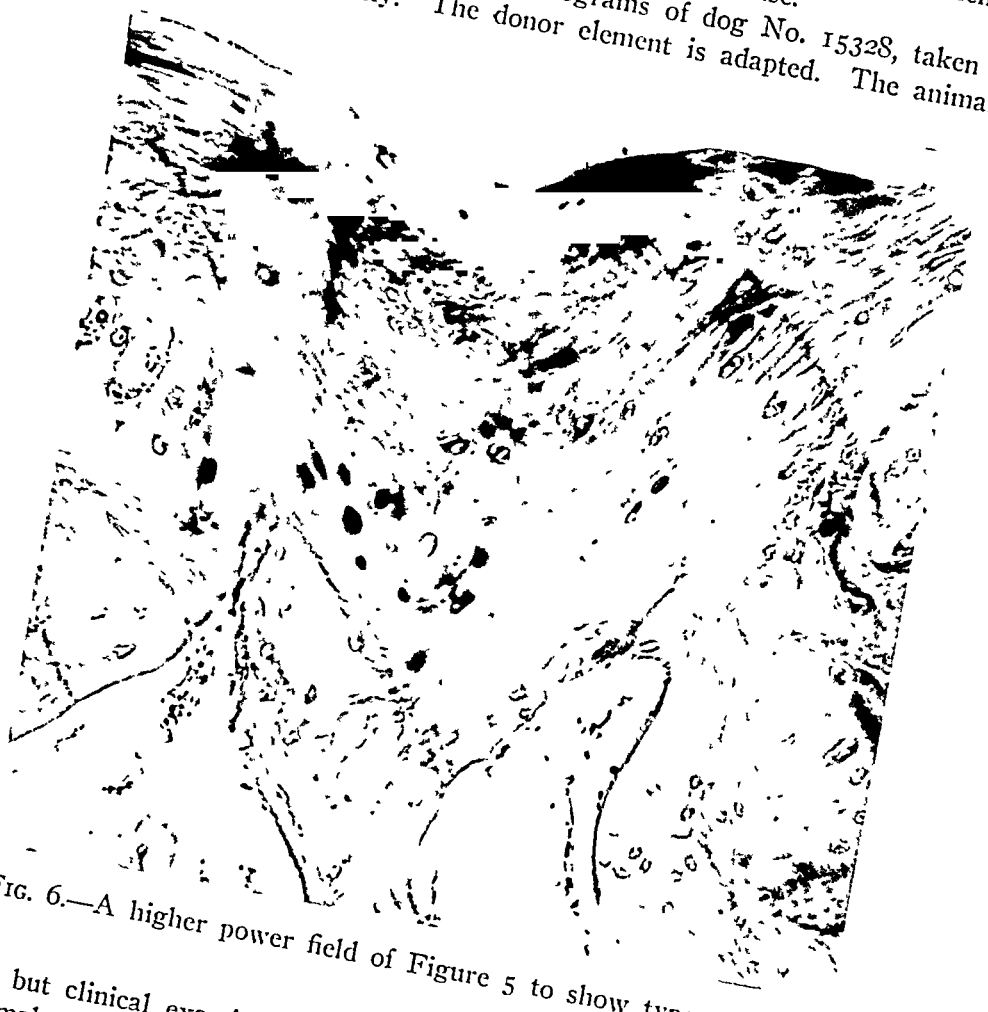


FIG. 6.—A higher power field of Figure 5 to show type of tissue.

Fig. 1.—(Middle right) shows roentgenograms of dog No. 15789, taken ten months postoperatively. The gross specimens are of the same shoulder four years and eight months later. (See protocol).

Fig. 2.—(Upper) shows the same humerus as in Figure 1 (middle right) four years and ten months later after removal. The articular surface of the glenoid is likewise shown with the normal side below it.

Fig. 2.—(Lower) shows roentgenograms of the humeri of the same animal, again, taken after removal following sacrifice.

Fig. 3.—Shows a low power field of the glenoid. Note the lipping of the lower margin of the glenoid with trabeculae forming over the articular cartilage and another articular surface superposed. At the upper limit where the long biceps tendon attaches there is some irregular cartilage production blending with some very dense fibrous tissue, poorly cellular. The supporting bone trabeculae in the middle portion are denser, thicker, and have few marrow cells.



FIG. 7.—A low power field of the tissue at the junction of the weight-bearing surface and flanged nail fixation surface.

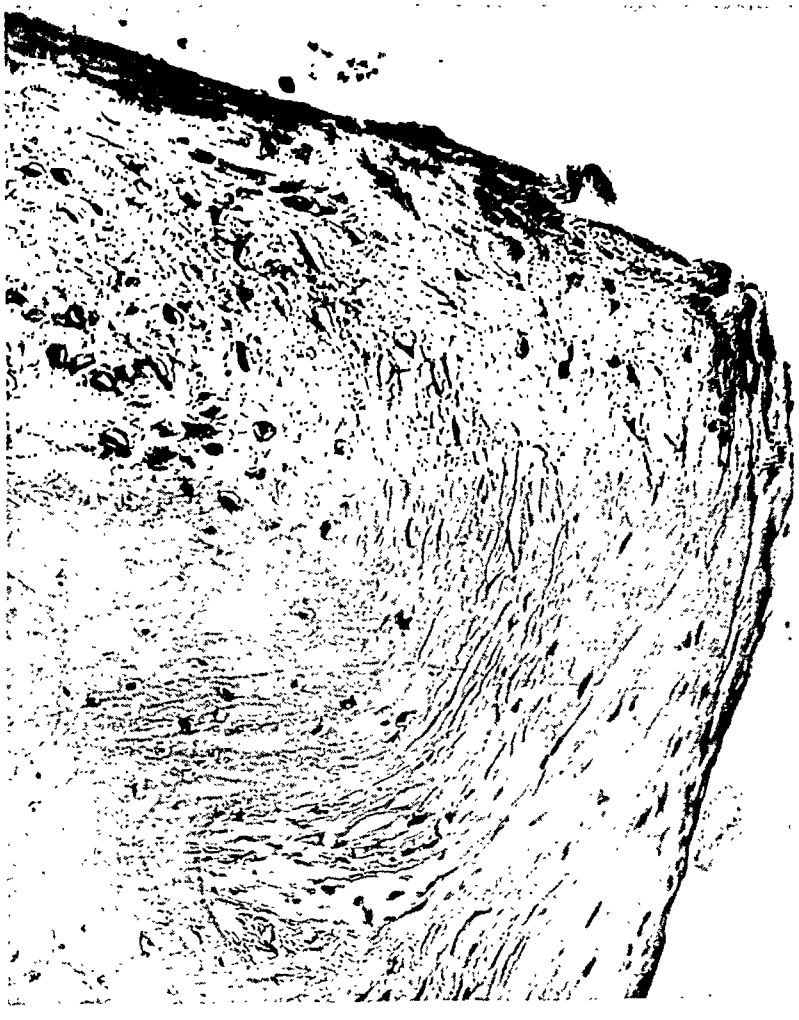


FIG. 8.—A higher power field of the junction area shown in Figure 7.

Fig. 4.—Shows a higher power of the central region where the cartilage was in the poorest condition. Note the thickened trabeculae and low cellular content of the marrow spaces.

Fig. 5.—Low power field in region of the greater tuberosity to show adaptation of a nonweight-bearing part of the humerus to the donor element. There are incompletely formed haversian units in which the lamellar structure is unevenly developed.

Fig. 6.—The tissue shown here is the same as in Figure 5 at higher magnification. Again, there is present a dense fibrocartilaginous tissue adjacent to a nonweight-bearing portion of the head. The trabecular support is not so heavy as in the weight-bearing part.

Fig. 7.—A low power field shows the region of the supporting structures where the flanged nail joins the weight-bearing surface of the head of the donor element. The pin portion shows an adaptive layer of dense lamellated fibrous tissue supported by heavy trabeculae. The weight-bearing portion shows a dense fibrocartilaginous adaptation.

Fig. 8.—The corner region of tissue in Figure 7 is here shown at higher magnification. There are no inflammatory cells present. The supporting bone trabeculae are quite heavy. The marrow spaces are not very cellular.

Fig. 9.—A region of the tissue surrounding the edge of the flanged nail. The separation of the dense fibrous layer from the underlying bone is an artefact. Before preparation for sectioning the fibrous and osseous layers were closely applied. Observe that there is no fibrocartilaginous reaction. The areolar tissue fills in the irregularities of the bone trabeculae. There are no signs of irritation or foreign body reaction. There are no inflammatory cells present.



FIG. 9.—The tissue about the edge of a nail flange.

Fig. 10.—A cross-section of the dense fibrous tissue which is the lining membrane surrounding the flanged nail. It is poorly cellular and poorly vascularized. The lamellae separated away easily and it was impossible to keep attached to the underlying bone trabeculae. This tissue is very similar to the lining membrane shown in Figure 9 around the edge of a flange in the nail.

DISCUSSION.—There appear to be three types of adaptive tissue surrounding the donor element. The tissue surrounding the nonweight-bearing part of the flanged nail is a dense stratified connective tissue lying on flattened bone trabeculae. It acts as a fibrous envelope and is relatively acellular and poorly vascularized. There are no inflammatory cells in it.

Where there is weight-bearing with compression stress the adaptive tissue is more fibrocartilaginous. Its character varies somewhat depending upon the supportive trabeculae.

Regions in which there is more stress than in the supportive tissue around

the flanged nail, as in the region of the greater tuberosity, the fibrous and fibrocartilaginous elements combine, the fibrocartilaginous elements dominating somewhat. Foreign body response and inflammatory tissue is singularly absent.

Grossly, the fibrous envelope about the flanged nail resembles the tissue

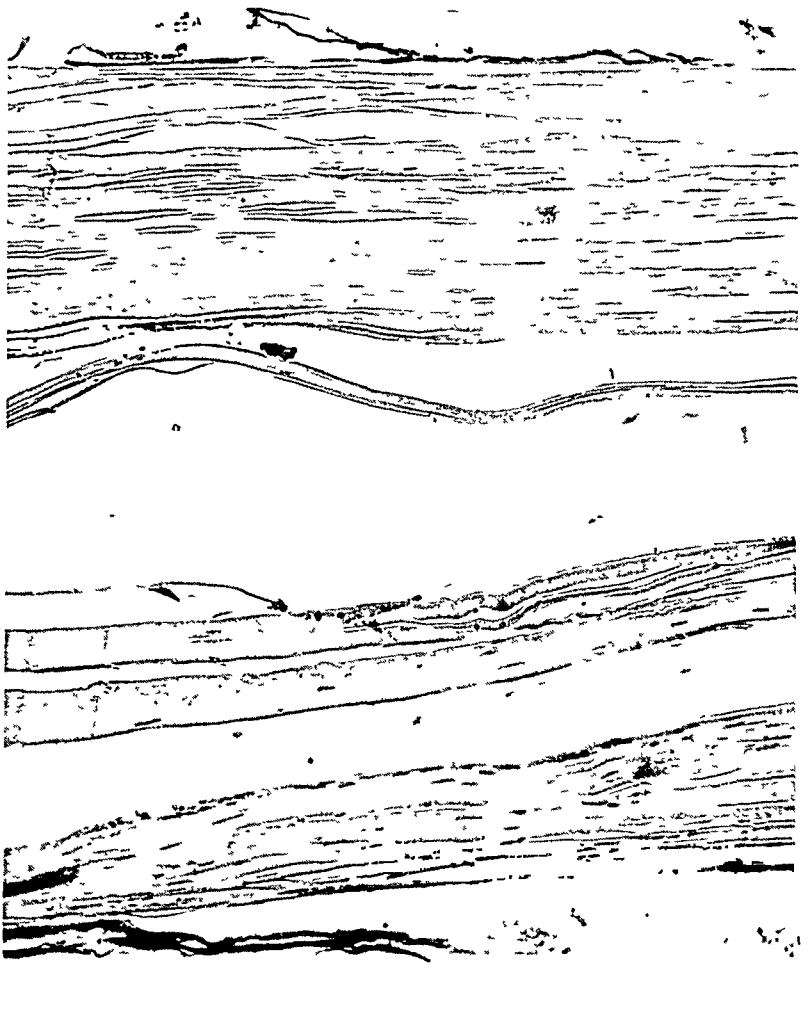


FIG. 10.—Stratified fibrous tissue surrounding flanged nail.

one sees in the pin tract of pinned hips in which the pin is removed after healing has taken place.[5]

Although these experiments are fragmentary and incomplete because of the interruption of war, they may be considered as pilot experiments in the study of the adaptive capacity of cancellous bone to weight-bearing stress. It may be that when this adaptive function is studied further and understood, replacement elements for parts of long bones destroyed by tumor, infection, or trauma can be used with greater confidence of success. A further study along these lines would give a much sounder basis for the clinical use of replacements than do the occasional clinical attempts adventured upon. In the long run,

there would be much less danger of the method coming into early disrepute because of ill considered or faulty application and its more extended use and wider understanding less delayed. Such instances of a method unjustifiably being thrown into discard because of early faulty application are not difficult to find in medical history. The early odium surrounding open reduction of fractures and internal fixation is only one example.

SUMMARY

A preliminary report on a study in articular replacement is given. Some of the adaptive capacity of cancellous bone to weight-bearing and other stress is considered. Further study along this line is indicated.

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# AN APPROACH TO RESECTIONS OF THE ESOPHAGUS AND GASTRIC CARDIA

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NEW YORK, N. Y.

SINCE malignant neoplasm of the esophagus and the cardiac end of the stomach are often histologically well-differentiated, and tend to remain localized for long periods before metastasis occurs, it might be expected that they would form a favorable group for surgical cure. At the present time, on the contrary, this group is treated with less success than any other gastro-intestinal cancer. There can be no doubt that one large factor in this lack of success is the frequent absence of arresting symptoms of disease until the lesions are far advanced, but it is also true that the possibilities of adequate treatment are still being worked out, and are not yet generally appreciated.

The isolated success of Torek over 30 years ago, proved that these tumors were not all hopeless, and during the following quarter century his technic was usually resorted to by those surgeons courageous enough to attempt it. The number of successes which were so achieved was very small. Furthermore, if the tumor was found to have crossed the diaphragm into the abdominal esophagus or stomach, or if it proved to be a tumor of gastric origin involving the esophagus by upward extension, this method could not be used, and the situation had to be considered hopeless. Even in those rare cases where removal proved successful, the patient was left with the necessity of submitting to further plastic operative procedures or of resorting to clumsy mechanical devices if he hoped to recover any semblance of eating his food. This operation has, for these reasons, never been a really satisfactory one, and the search for a better solution has been unremitting.

Within the past ten years improvements in our ability to maintain respiration under anesthesia during prolonged intrathoracic procedures, combined with a better appreciation of the rôle of nutritional and fluid needs before operation and during the recovery period, have enabled great advances to be made. Outstanding among these has been the demonstration that direct anastomosis between the stomach and proximal esophagus could be achieved, and that the diaphragm could be crossed without fear.[1] It has also been shown that anastomosis between jejunum and esophagus, either in the abdomen or in the chest, is feasible. While several surgeons have published impressive series of successful resections, and many others have reported isolated or small groups of cases, it is evident that each surgeon has developed his own variations in applying established principles to his particular problems, and that no single generally accepted method has emerged. It seems worth while for this reason to publish the small series here reported.

A total of 70 patients with proven malignancy involving the esophagus were operated upon at the Presbyterian Hospital in the five-year period between

January 1, 1941 and January 1, 1946. In 51 patients the tumor originated in the esophagus; it involved the esophagus secondarily by extension upward from the stomach in 19 patients. An additional group of five patients is included in which the esophagus was not involved, but in which lesions of the stomach close to the cardia were resected through the same approach used in those cases which had extended to the esophagus. Thirty-seven patients, or 52 per cent of the group involving the esophagus, were considered inoperable. Of these, 19 patients were treated by palliative gastrostomy only because the lesion was too far advanced to consider resection; all of these were lesions originating in the esophagus. An operation to determine resectability was carried out in the remaining 18 patients; in 11 of these the lesion originated in the esophagus and the approach was through the chest; in seven the lesion originated in the stomach, and in six of these it was possible to determine operability without opening the chest.

Radical resection of the tumor was carried out on 33 patients, or 48 per cent of the group involving the esophagus. The tumor originated in the esophagus in 21 of these; in the remaining 12 it originated in the stomach. Discussion of the procedures used in these cases, as well as in the five high gastric lesions in which the esophagus was not involved must be subdivided according to the site of the lesion, since this factor determined the method used.

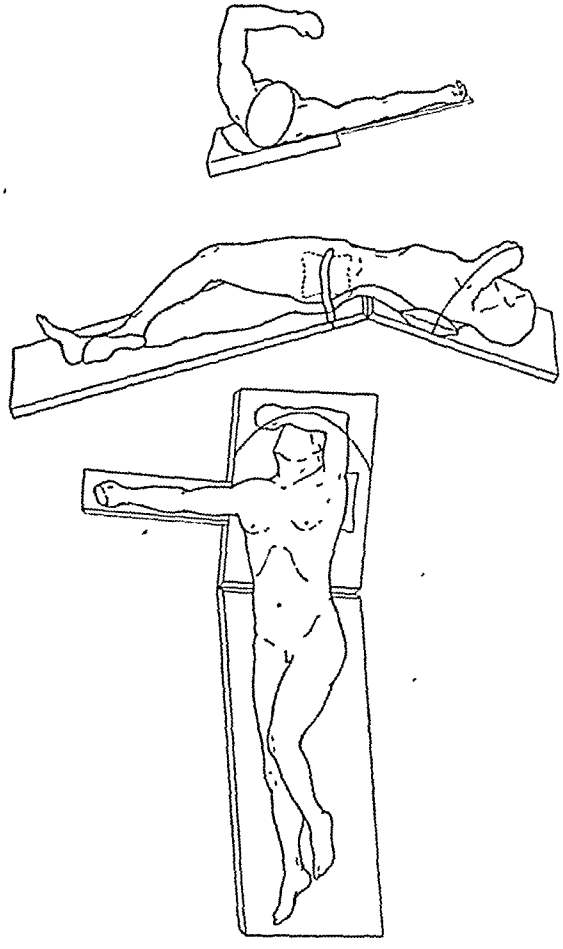


FIG. 1.—Position of the patient for abdominothoracic incision. The table is tilted during abdominal exploration; if the tumor is removable it is rotated back to horizontal, so that the lateral chest wall is exposed. During closure the head and feet are raised to bring the wound edges together.

### TUMORS OF THE UPPER THORACIC ESOPHAGUS

The upper level of resection was at or above the inferior surface of the aortic arch in ten patients. Five of these were resected by a procedure of the Torek-type, a right-sided approach being used in all but one. This approach enables the tumor to be exposed readily by dividing the overlying azygos vein, but if the adventitia of the aorta is involved, this fact (which renders resection impossible) may not be uncovered until after considerable dissection has been done. In this series only one patient survived the immediate postoperative period, an operative mortality of 80 per cent, which is considerably higher

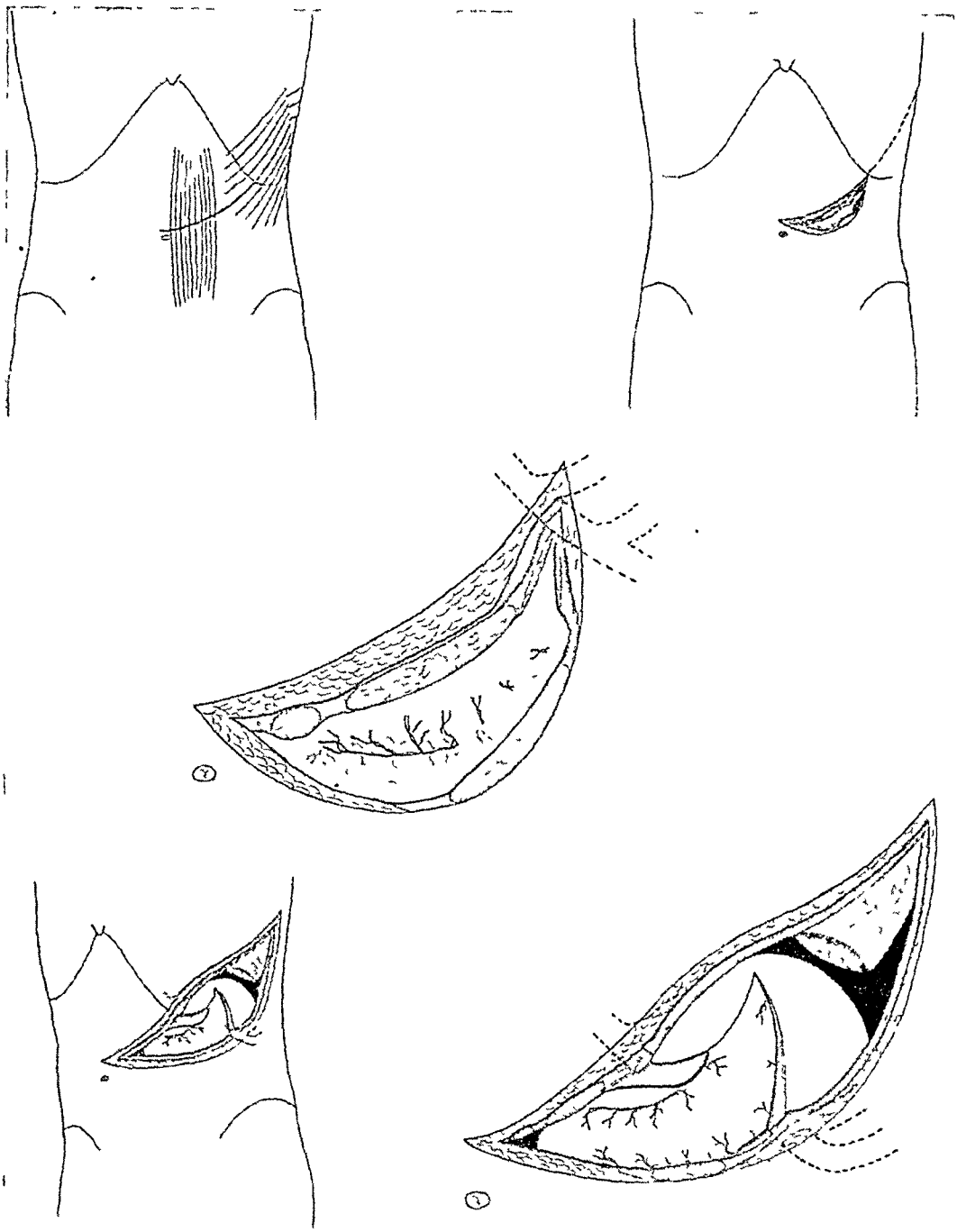


FIG. 2.—The operative incision in the abdominothoracic approach. The abdominal portion is first made and exploration carried out; if the tumor is removable the table is turned and the incision carried up over the 8th interspace. The diaphragm is then divided.

than in any other group. Because of these facts the Torek procedure is now considered to be indicated only when the tumor extends into the cervical esophagus.

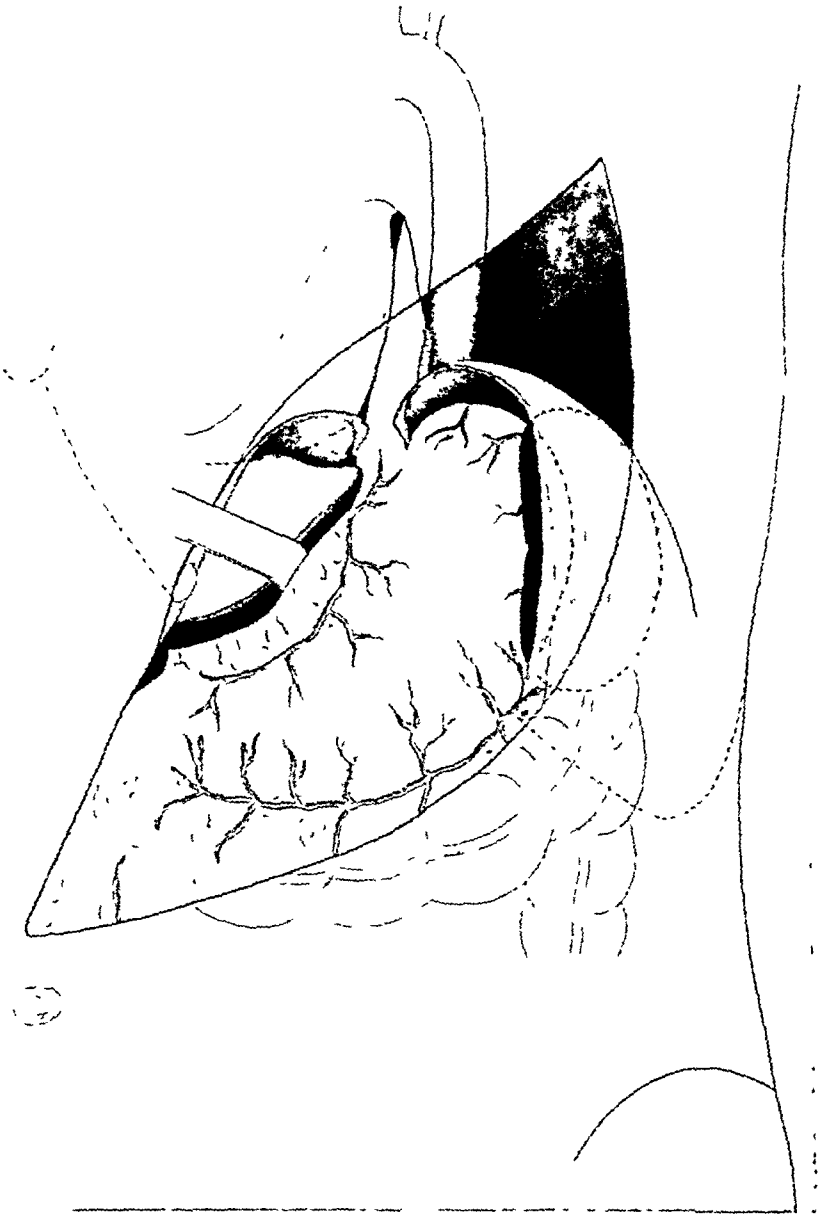


FIG. 3.—After complete division of the diaphragm the lower esophagus and upper stomach is clearly exposed. Exposure can readily be carried upward as high as the lung hilus, less readily to the aortic arch. The pylorus is readily accessible.

A left-sided approach, through a posterolateral incision with division of one or more ribs posteriorly, and either resection of a rib segment or incision through an intercostal space followed by wide resection of the esophagus from well above the lesion to the gastric cardia, and esophagogastrostomy lateral to the aortic arch, is now considered the procedure of choice for these lesions.

Annals of Surgery
August, 1946

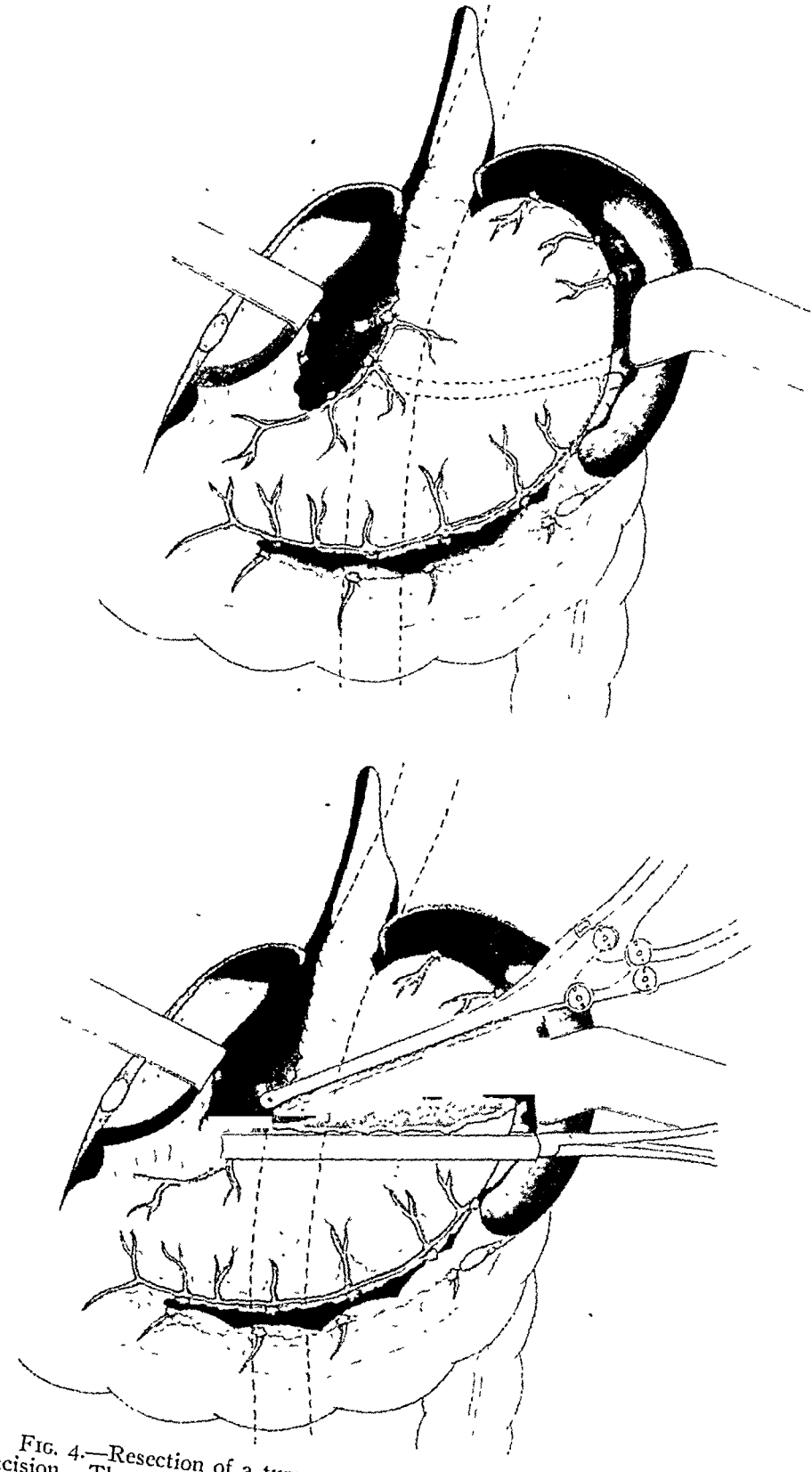


FIG. 4.—Resection of a tumor of the cardia through a combined incision. The gastrocolic and gastrohepatic omenta have been divided (above) and the stomach is being transected (below).

It was carried out in five patients. Operability can usually be determined quickly: if inoperable the thorax is closed and an immediate gastrostomy may be established. If the tumor can be removed, the right pleural cavity will often be entered since the mediastinal pleura on that side is frequently closely

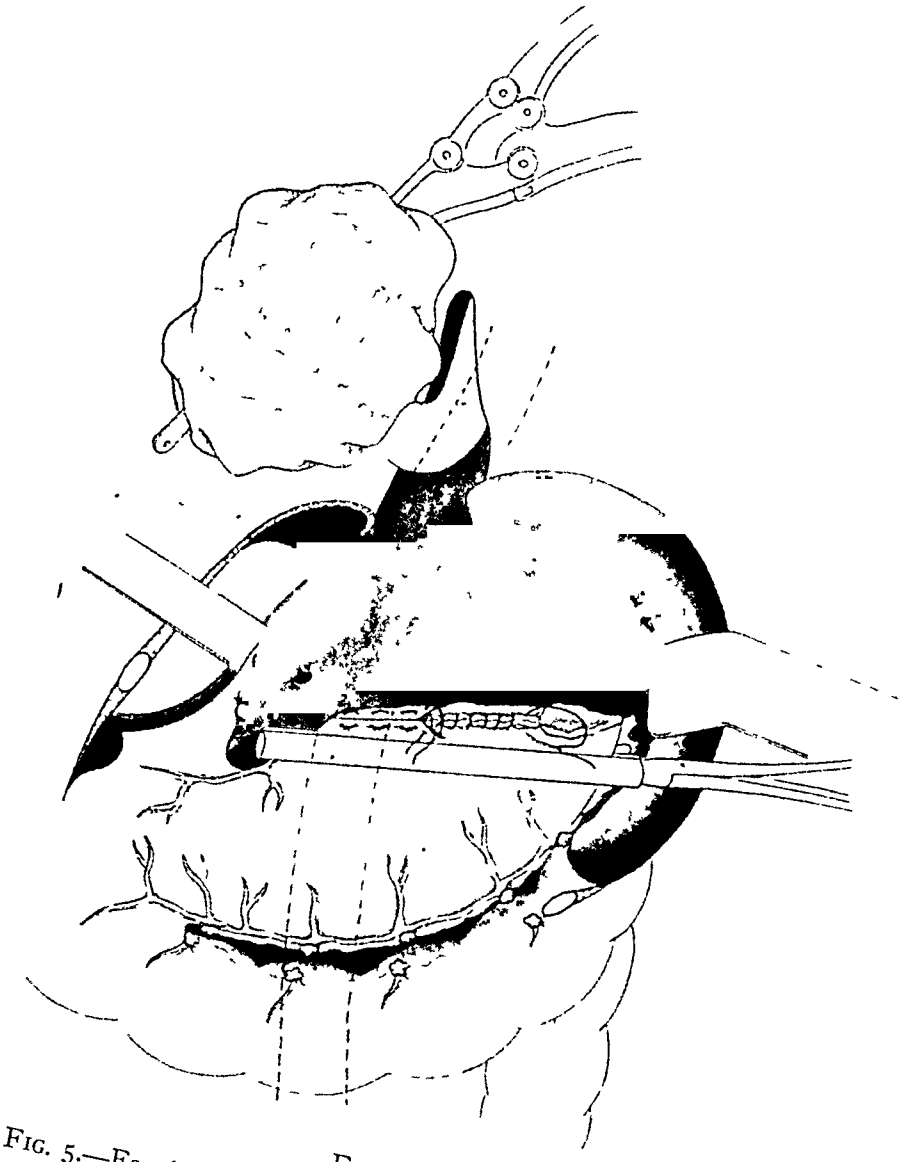


FIG. 5-A

FIG. 5.—Esophagogastrostomy following resection of a tumor of the gastric cardia through a combined incision. The technic is essentially the same when the gastric fundus is used following resection of an esophageal tumor.
(A) The tumor is turned upward and the cut-end of the stomach is closed in two layers.

adherent to the tumor. The esophagus must be freed down to the diaphragm and up to the apex of the chest. The diaphragm is then opened from its dome to the esophageal hiatus and the stomach mobilized by dividing the gastrolienal and gastrocolic omenta, as well as the gastrohepatic omentum including the left gastric artery, until the fundus can be rotated without tension well above the lesion. The esophagus is now divided at the cardia and drawn up behind

the aortic arch to emerge above it between the carotid and subclavian arteries. The cardiac orifice is closed, and the gastric fundus is lifted upward into the chest and secured with its apex lateral to and above the aortic arch, while the body of the stomach lies in the mediastinum in a position corresponding to esophagus. It is surprising how readily the stomach can be brought up—mobilization of the duodenum has not been necessary in any instance. The

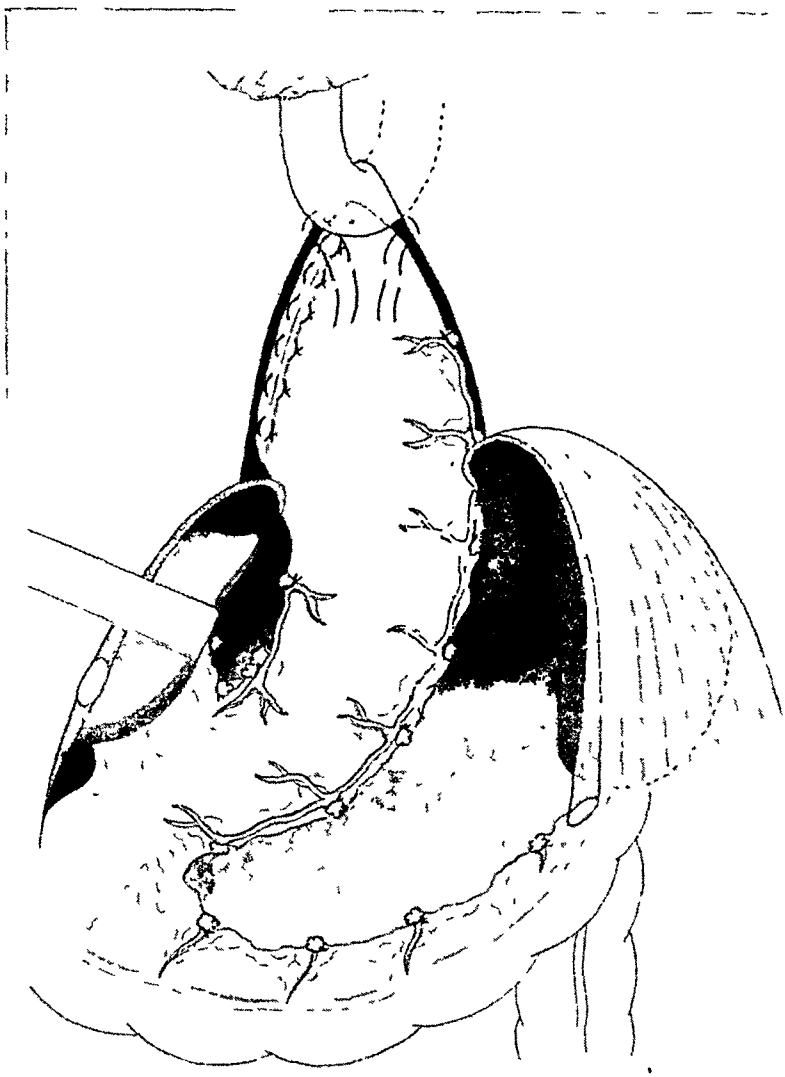


FIG. 5-B

FIG. 5.—(B) The remainder of the stomach rotated upward and anchored in the mediastinum.

esophagus is now divided and its cut-end anastomosed to a vertical incision in the fundus of the stomach, as illustrated in Figure 5. The diaphragm is closed around the stomach and the chest closed with an intercostal catheter drain.

Two of the five patients subjected to this procedure survived, an operative mortality of 60 per cent. One of these died of metastatic tumor two years later, the other is apparently well two years after operation.

The upper level of resection was below the level of the aortic arch in 11 patients. In nine of these resection was carried out through a thoracic approach similar to that used for the higher lesions with esophagogastrostomy below the arch. The level of incision is determined by the expected level of the lesion,

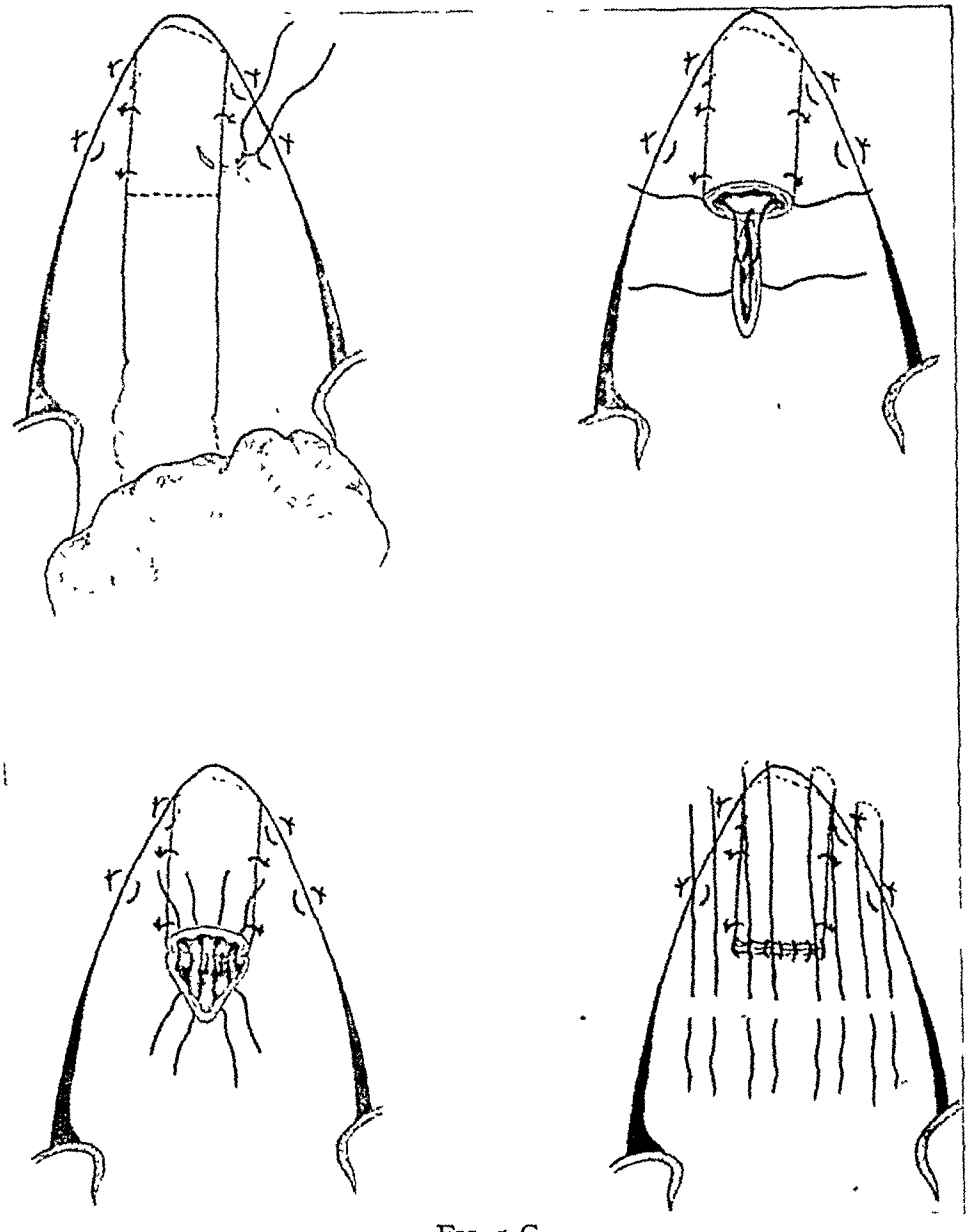


FIG. 5-C

FIG. 5.—(C) Steps in the anastomosis: The esophagus is first sutured to the stomach; after removing the involved esophagus, a vertical incision is made in the gastric wall; interrupted sutures through all layers unite esophagus to stomach; mattress sutures are used to draw the anterior gastric wall upward over the anastomosis and anchor it to overlying pleura.

with extension upward by dividing the necks of the overlying ribs always possible if the upper level of safe resection proves to be too high to permit anastomosis below the arch. In two patients the level was so low that the combined abdominothoracic incision described below was used, in order to determine operability by exploring the abdomen before entering the chest. In all

cases the esophagus is freed from aortic arch to cardia and the diaphragm is divided so as to permit mobilization of the gastric fundus and cardia. Depending on the level of the lesion, it may or may not be necessary to divide the left gastric artery, but mobilization never has to be as extensive as in the higher or lower level groups. The cardiac orifice of the stomach is closed and the fundus rotated upward into the mediastinum where it is held by sutures to the cut edges of the pulmonary ligament. The esophagus is then divided and its cut-

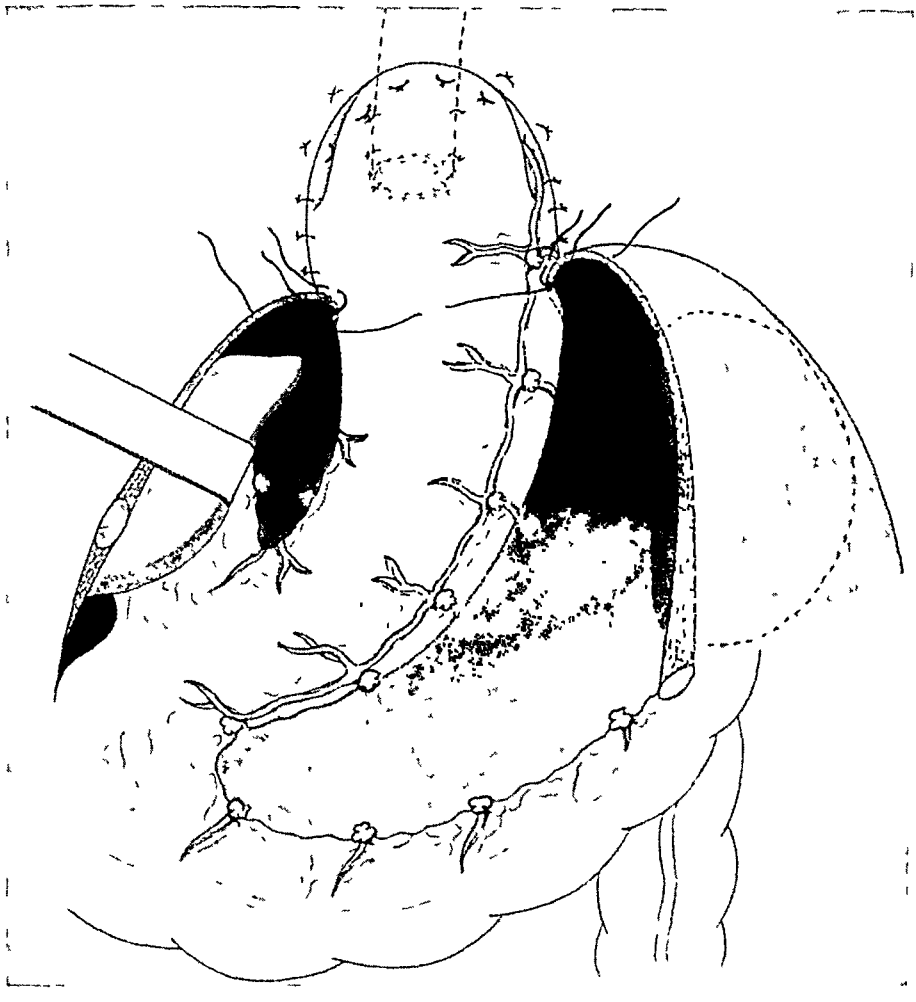


FIG. 5-D

FIG. 5.—(D) The anastomosis completed.

end anastomosed to a vertical incision in the fundus of the stomach, as illustrated in Figure 5. The diaphragm is closed and the chest drained with an intercostal catheter.

Of these 11 patients, five died between three and 19 days after operation, an operative mortality of 45 per cent. One survivor died six months after operation of inanition, though apparently free of malignant disease. Three others succumbed to metastatic recurrence a year, or more, after operation, and the remaining two are apparently well eight and six months after operation.

TUMORS OF THE STOMACH INVADING THE ESOPHAGUS

In ten of 12 patients the tumor, which involved the esophagus secondarily by invasion upward from the stomach, was resected through the combined abdominothoracic approach, as shown in Figures 1 and 2. In the other two a thoracic approach was used, as in the lower esophageal lesions described above. Because many of these tumors are inoperable due to extensive invasion or distant metastases within the abdomen, the latter is first opened through an oblique incision extending from the costal margin at the level of the eighth interspace to a point just to the right of the midline, about two cm. above the umbilicus. If resection is not considered justified (as was the case in the six patients mentioned previously) a palliative gastrostomy may be established, and the patient is spared the added risk of a thoracic operation. If the tumor seems removable the incision is extended directly upward into the chest over the 8th interspace to the posterior axillary line. One or more ribs may have to be divided, though adequate exposure is usually obtained without rib resection. The diaphragm is then divided from its origin at the costal margin between 8th and 9th ribs to the esophageal hiatus. By tilting and breaking the operating table a very wide exposure of the subphrenic region can thus be obtained (Fig. 3). The esophagus is now freed upward as far as is necessary to obtain a good stump for anastomosis, and the stomach, including great omentum and, if necessary, the spleen, is freed from its attachments to liver and colon as far toward the pylorus as necessary. Special care should be taken to remove the group of lymph nodes around the celiac axis when the left gastric artery is divided.

The extent of gastric resection will depend on the extent of the lesion, but it seems probable that in this series there has been a tendency to try to save too much stomach. The procedure, as illustrated in Figures 4 and 5, in which the cut-end of the stomach is closed and brought upward into the mediastinum and a separate anastomosis is made between the cut-end of the esophagus and an incision in the anterior gastric wall, is considered ideal. It is possible, however, only when the lesion is small and close to the cardia. This was the case in only two of the 11 patients in this series. In nine patients the anastomosis was performed instead between the esophagus and the cut-end of the stomach, six times at the greater curvature end, and three times at the lesser. Five of these patients survived for sufficient periods to demonstrate that such an anastomosis can heal and function well, though it is generally condemned by most authors. Probably the greatest risk in such a procedure is the tendency to cut the stomach obliquely, in lesions which extend downward along the lesser curvature, in an effort to save a portion of uninvolved fundus. This results in a long tube-like gastric remnant with questionable blood supply, into the end of which the esophagus is invaginated with difficulty. The only death due to sloughing of the mobilized stomach occurred in such a case.

In the remaining case a total gastrectomy and intrathoracic esophagojejunostomy was carried out. This patient had a very extensive lesion and died during the postoperative period, but it is now felt that this procedure should

be used in most cases in which more than half of the lesser curvature is involved. This opinion is based not only on the theoretic disadvantages of anastomoses between esophagus and the cut-end of a small gastric remnant, but also on experience with some survivors who have developed difficulties due to spasm of the pylorus.

Six of the 12 patients in this group died postoperatively, an operative mortality of 50 per cent. Of the survivors, three have died of generalized metastases, 7, 16 and 18 months after operation. The remaining three are living and apparently free of disease 5, 6 and 15 months after operation.

### HIGH GASTRIC TUMORS NOT INVOLVING ESOPHAGUS

Five patients were operated upon using the approach described above because their lesions were so high that it was thought a combined approach might be needed. In two, the procedure was carried out entirely within the abdomen. One of these patients proved to have a leiomyoma of the stomach which was locally removed; the other patient had an extensive carcinoma which, however, did not involve the abdominal esophagus. A subtotal gastrec-

TABLE I

| Procedure | Right Posterior Thoracic | Left Posterior Thoracic | Anterolateral Thoraco-abdominal | Abdominal Segment Only | Abdominal Without Exploration | Total Number of Cases | Operative Mortality (Per Cent) |
|---|---|---|---|---|---|---|---|
| Torek | 4 | 1 | | | | 5 | 80 |
| Anastomosis above arch | | 5 | | | | 5 | 60 |
| Anastomosis below arch | | 9 | 2 | | | 11 | 45 |
| Esophagogastrectomy and anastomosis | | 2 | 10 | | | 12 | 50 |
| Total gastrectomy and gastrojejunostomy (intra-abdominal) | | | 1 | | | 1 | 0 |
| Partial gastrectomy and subphrenic esophagogastrostomy | | | 1 | 1 | | 2 | 0 |
| Partial gastrectomy and gastrorrhaphy | | | 1 | 1 | | 2 | 0 |
| Palliative gastrostomy | 1 | 10 | 1 | 6 | 19 | 37 | 18 |
| Total | 5 | 27 | 16 | 8 | 19 | 75 | |

tomy with subphrenic esophagogastrostomy was performed. In the other three patients a combined abdominothoracic incision was made, but the thoracic esophagus was not disturbed. One of these patients had a large leiomyosarcoma of the fundus resected locally. The second had a partial gastrectomy for carcinoma with subphrenic esophagogastrostomy and the third a total gastrectomy for carcinoma with subphrenic esophagojejunostomy.

It now seems probable that the three patients in this group with carcinoma, two of whom are dead, and one dying of metastases, would have had a better chance of cure if the more radical combined abdominothoracic resection, with anastomosis in the thorax had been done. There was, however, no immediate postoperative mortality in this group. The two patients with leiomyoma and leiomyosarcoma locally removed are living and well, 2 and 2.5 years after operation.

SUMMARY

The various methods of resection of tumors of the esophagus and gastric cardia have been discussed. The experience with 75 patients treated at the Presbyterian Hospital, in New York, during the five-year period from January 1, 1941 to January 1, 1946, has been reviewed, with special reference to the various approaches to the lesions. The procedures carried out and their results are as follows:

1. Esophagectomy with cervical esophagostomy and gastrostomy (the Torek procedure). This procedure, through a right-sided thoracotomy incision is now considered perhaps justified only in lesions involving the lower cervical esophagus. Five cases, 80 per cent operative mortality, no cure.

2. Esophagectomy with esophagogastrostomy lateral to the aortic arch carried out through a left-sided posterior thoracic incision. Five cases, 60 per cent operative mortality, one patient well two years.

3. Esophagectomy with esophagogastrostomy below the aortic arch: nine cases carried out through posterior thoracic incisions, two through an anterolateral combined abdominothoracic incision. Eleven cases, 45 per cent operative mortality, two patients well eight and six months.

4. Esophagogastrectomy with intrathoracic esophagogastrostomy or esophagojejunostomy; two cases carried out through posterior thoracic incisions, ten cases through an anterolateral combined abdominothoracic incision. Twelve cases, 50 per cent operative mortality, three patients well five to 15 months.

5. Partial or complete gastrectomy with intra-abdominal esophagogastrostomy, esophagojejunostomy or gastrorrhaphy: three cases carried out through a combined abdominothoracic incision, two through the abdominal portion only. Five cases, no operative mortality, two patients well 2 and 2.5 years.

6. Palliative gastrostomy: 19 carried out without exploration, 11 after determination of inoperability by thoracotomy, seven after determination of inoperability by the abdominal portion of a combined incision. Thirty-seven cases, 8 per cent operative mortality, longest survival 20 months.

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# A REPORT ON TRENCH FOOT AND COLD INJURIES IN THE EUROPEAN THEATER OF OPERATIONS
## 1944-1945

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NEW YORK, N. Y.

A TRENCH FOOT STUDY PROJECT was initiated at the 108th General (U.S.) Hospital, November 15, 1944, by the Chief Surgeon, E.T.O., under the supervision of the Chief Consultant in Surgery and Staff of the 108th General Hospital which was augmented for the endeavor. The purpose of the investigation was to study the pathologic and physiologic changes occurring in such injury and to establish simple methods of rapid *triage* of the patients. During the following three months approximately 500 cases were carefully examined by the group and over 5,000 cases were admitted to the hospital.

"Trench foot" is a diagnostic term used by the U. S. Army Medical Corps to describe the cold injury resulting from prolonged exposure to just-above-freezing-temperature (34° to 40° F.). It has occurred almost exclusively in combat infantry riflemen who were forced into immobility by enemy action. "Frost-bite" is the term used to describe the cold injury resulting from exposure to below-freezing-temperatures—either "ground type" occurring in the ground forces, or "high altitude type" occurring in combat air crews. "Immersion foot" designates the cold injury resulting from prolonged exposure of the feet to cold water. For administrative reasons, these injuries are described as different clinical entities, but it now appears that they all produce similar pathologic changes and can be treated identically. The U. S. Army Medical Corps continues to use the multiple diagnostic terms as they portray a graphic picture of the conditions existing when the injuries were sustained.

During World War I, the French Army reported trench foot as accounting for 3.02 per cent of their battle casualties. During the Italian campaign of 1943 the incidence in the French forces increased to around 10 per cent. Until October 1, 1944, the incidence with the French troops was again around three per cent, which is comparable to the figures in our Army during this period. Following the early November offensive, and again after the German counter-offensive in December, 1944, the U. S. Army casualties increased at an alarming rate, several weeks reaching 50 per cent of battle casualties. During the freezing temperatures of January and February, 1945, a third increase in casualties occurred. This group was classified as cold injuries, ground type, but in this report the two injuries are not separated in the statistical reports. The minor difference in the clinical picture of the injuries will be described later.

In the British Forces operating in Holland and Belgium up to December 31, 1945, only 44 cases of trench foot had been reported. At a joint meeting with the British Medical Consultants in December, 1944, the fact was stressed

TABLE I

TOTAL MONTHLY ADMISSIONS TO HOSPITALS ON CONTINENT

(*Europe Only*)

| Date | Battle Casualty | Cold Injuries (Trench Foot—Frost-bite) |
|---|---|---|
| Nov. 1944 | 41,793 | 6,869 |
| Dec. 1944 | 37,336 | 11,469 |
| Jan. 1945 | 40,107 | 17,457 |
| Feb. 1945 | 26,834 | 7,740 |
| Mar. 1945 | 31,156 | 2,151 |
| Apr. 1945 | 29,997 | 461 |

that the British shoe is so constructed and fitted that the front flaps approximate each other before lacing and, therefore, cannot become constricting. Second, in the British Army foot discipline is greatly emphasized and definitely made the joint responsibility of the soldier and his commanding officer. The soldier is repeatedly told that cold is just as dangerous as enemy weapons. Third, during the commitment of troops under conditions resulting in "trench foot," there is a strict rotation policy which relieves the troops before a major injury can occur.

### ETIOLOGIC FACTORS IN THE 1944-45 E.T.O. THEATER

*In trench foot,* the sequence of events leading to the injury followed a fairly constant pattern. The combat infantry soldier is forced into immobility in a wet foxhole for a prolonged period of time. During this period, he first notices tingling or complains of a stinging sensation in his feet, which may become quite intense. After a period of exposure, the feet become numb and finally anesthetic, "like blocks of ice." When the attack is ordered, or he is relieved, walking causes severe burning pain; and on the removal of his shoes, the feet become swollen and warm. Three factors were always present in the carefully examined cases. First, wet cold; second, a prolonged exposure in a relatively immobile position; and third, physical activity following the exposure. Of these factors, wet cold is undoubtedly the most important. Peak casualties always followed periods of wet cold weather.

The secondary etiologic factors which combine with wet cold to produce the final injury are important since they are often correctable (Table II). *Combat activity* was always followed by an increase in trench foot casualties. *Fifty per cent* of the soldiers were injured in their first combat experience. *Proper* and *adequate* foot gear was unavailable in 80 per cent of the casualties during the November, 1944, offensive. After the U. S. Army overshoe was issued, this foot gear proved inadequate in many instances. The important fact that a boot should be designed for rapid removal is not considered in the standard American and British foot gear. Soldiers repeatedly use this excuse for their failure to replace wet socks under combat conditions.

*Constriction of the foot* and ankle by improperly fitted shoes was difficult to evaluate. Many soldiers complained that their "shoes felt too small after several days of exposure" but the first sign of cold injury is edema and probably caused this complaint.

*Prolonged dependency and immobility of the feet* appeared important in a few cases occurring in tank crews and artillery squads. These soldiers alone had either dry feet (tank crews) or were in a position to maintain an adequate rotation policy. This suggests that dependency and immobility increase the susceptibility of the feet to cold injury. The soldiers with a history of *previous foot trouble,* either cold injury or other conditions, sustained milder injuries than the entire group examined. Only 20 per cent suffered second- or third-degree injuries as compared to 63 per cent with similar injuries for the entire group. In other words, previous foot trouble made the soldier "foot conscious" and medical aid was requested early.

TABLE II

HEADQUARTERS 108TH (U.S.) GENERAL HOSPITAL, APO 887

ETIOLOGIC FACTORS IN TRENCH FOOT AND COLD INJURIES IN THE E.T.O. 1944–45

| Date | Nov. 20 1944 | Dec. 21 1944 | Dec. 28 1944 | Jan. 20 1945 | Feb 28 1945 |
|---|---|---|---|---|---|
| Number Cases Examined | 100 | 100 | 100 | 100 | 100 |
| Type of Troops Affected: | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent |
| Combat Troops out of Front Lines | 98 | 98 | 99 | 100 | 83 |
| Infantry | | 76 | 80 | 49 | 74 |
| Armored infantry | | 18 | 15 | 29 | 7 |
| Paratroop infantry | | | | 6 | |
| Airborne infantry | | | 2 | 4 | |
| Total infantry | | 94 | 95 | 88 | 81 |
| Tanks | | 5 | | 3 | |
| Field artillery | | 1 | 2 | 5 | 2 |
| Casuals in reinforcement depots | | | 2 | 4 | 17 |
| Total Combat Experience: | | | | | |
| 0 to 9 days | | 50 | 42 | 40 | 51 |
| 10 to 19 days | | 31 | 23 | 33 | 15 |
| 20 to 29 days | | 17 | 21 | 7 | 9 |
| Over 30 days | | 2 | 14 | 20 | 25 |
| Living Conditions while in Combat | | | | | |
| In foxholes | 76 | 76 | 89 | 82 | 81 |
| In dugouts | 8 | 1 | 1 | 3 | |
| In unheated billets | 6 | 5 | 2 | 3 | 4 |
| In tanks or half-tracks | 6 | 6 | 2 | 6 | |
| On open ground | | 5 | 1 | 3 | |
| Others | 4 | 7 | 5 | 3 | 15 |
| Supply of Foot Gear in Combat Zone | | | | | |
| Socks (3 or more pairs) | 96 | 46 | 42 | 58 | 90 |
| Arctics, Overshoes or Shoe Pacs: | | | | | |
| None issued | 52 | 38 | 36 | 17 | 10 |
| Issued only after cold injury | 28 | 10 | 4 | 5 | |
| Discarded before combat | 2 | 12 | 15 | 15 | 2 |
| Total combat troops without protective foot gear | 82 | 60 | 55 | 36 | 12 |
| Issued but inadequate: | | | | | |
| Wading canals or rivers | 9 | 23 | 9 | 4 | 8 |
| Canvas type overshoe leaking | 4 | 10 | 15 | 13 | 16 |
| Rain or snow over tops | 3 | 15 | 8 | 15 | 4 |
| Shoe pac caused excess sweating | | | 2 | 4 | 43 |
| Noncombat troops without arctics | | | 2 | 4 | 17 |
| History of Previous Foot Trouble: | | | | | |
| Previous cold injury | 6 | 14 | 17 | 17 | 22 |
| Hyperhidrosis | 26 | 30 | 34 | 17 | 7 |
| Other foot disorders previously | 10 | 13 | 13 | 5 | 9 |

The most important *correctible secondary factor* is an improved rotation policy for troops during combat activity. If a few men are relieved for only an hour daily from each group, adequate foot care could be required under supervision, if necessary. This was almost impossible when the tactical situation required troops to wade streams and "dig in" until relief arrived. Company commanders most successful in avoiding casualties under these circumstances, required each soldier to exchange old wet socks for clean dry ones when daily food rations were issued. This often required the mess sergeant to deliver food and clean socks from foxhole to foxhole during the hours of darkness.

### REACTION OF THE SKIN TO COLD

Lewis,[1] Stray,[2] and Kreyberg[3] agree that the immediate reaction of the skin to cold is a blanch in color. This phenomenon is caused by the contraction of the terminal arterioles and veins. It is doubtful that the distal capillary loops are involved but the reduced blood flow causes the lumen of these vessels to appear smaller in diameter.

The sensation of cold appears as the skin temperatures are reduced to 25° to 15° C. At these temperatures, the skin develops a bluish color (cyanosis) indicating local oxygen deficiency, *i.e.,* local tissue metabolism exceeds local oxygen supply. As the temperatures are lowered to 10° to 8° C., the bluish color gradually changes to purple and finally a bright red or pink. This paradoxical color change, indicating excess oxygen locally, is apparently the result of decreasing tissue metabolism and a lower oxygen dissociation from the blood at these temperatures.

Each of the above color changes may be transient or prolonged depending upon the degree of cold, duration of exposure and speed of wind currents. If the surrounding temperature is returned to normal after a short exposure, no further reaction will occur. If prolonged, secondary pathologic reactions may follow. The transition between these physiologic responses and pathologic reactions is altogether too indefinite. Spellman[4] has reported minimal blood flow in the legs at temperatures between 20° to 15° C. Prolonged exposure at these temperatures, the "just-above-freezing" encountered by the troops, produces definite pathologic changes.

### CLINICAL TYPES IN TRENCH FOOT

*In mild or first-degree injuries,* (36.4 per cent)* the color changes and sensations encountered during exposure are quite similar to those described above. When placed in a warm environment, the foot develops a bright red flush with a slight elevation of skin temperature. The great vessels show increased pulsation for a few hours and the skin appears thicker from mild edema (Fig. 1). The patients experience "tingling" of the feet early, and later complain of itching, burning or mild throbbing pain. This so-called "hyper-

* Based on 500 cases discharged from 108th General Hospital.

emic" or "inflammatory" stage subsided within three days (1 to 6 days), after which the foot assumed a normal appearance. All cases were walking without pain within 4.2 days (0–10 days) after exposure. This group of cases were returned to full duty after a short period of rehabilitation.

In the second- and third-degree injuries, the color changes are more pronounced during the period of exposure. The moderate cases describe the



FIG. 1.—Trench foot, first-degree, early, showing persistent red flush and edema.

foot as pale with areas of blue and purple discoloration. Severe cases describe the foot as "marble white" in color. Difficulty in walking and anesthesia of the feet increased with duration of exposure.

In the *second-degree injuries,* (55.6 per cent)* the reaction after exposure is more severe, with hyperemia, pulsation of the larger vessels and throbbing pain which may last for several days (Fig. 2). Blisters appear and minute areas of intracutaneous ecchymosis develops on the weight-bearing surface of the foot and toes (Fig. 2B). The edema subsided on the average of 8.4 days (6–10 days) and was followed by varying degrees of scaling, leaving a sensitive skin that perspired profusely. When placed in warm environment or during exercise, the feet become warm and painful. Exposure

* Based on 500 cases discharged from 108th General Hospital.

to a cold or cool environment is more comfortable for the patient. This is in contrast to the recovering cases with high altitude frost-bite whose hands become painful when exposed to cold.

Most of these cases developed a typical foot deformity. The longitudinal and transverse arches would disappear and the great toe contract into a semi-dorsiflexion position. Deep-seated pain continues for weeks usually in the first metatarsal-phalangeal joint and across the plantar surface of the foot, especially when soldiers were given trial marches or required to stand guard of two-hour periods. Under the urgency of the time, most of these cases were returned to limited duty, usually requiring guard duty in the rear echelon. Many were rehospitalized and later discharged as unfit for any type of duty.

In the *third-degree injuries,* (eight per cent)* the initial reaction was intense and usually develops within three to four hours after the foot was placed in a warm environment (Fig. 3A). All the cardinal signs of inflammation are present—marked edema, heat, redness and burning throbbing pain. Large blisters, intracutaneous ecchymosis with superficial skin necrosis give the appearance of threatening gangrene of the foot and digits (Fig. 3B). The inflammatory stage averaged 12.4 days (7–32 days), only rare cases showing persistent edema for more than 14 days. The superficial layers gradually mummified and finally desquamated (Fig. 3C) shedding the shrunken gangrenous shell of epidermis like a cocoon, leaving a pink sensitive skin resembling the foot of a baby (Fig. 3D). On dependency, the skin assumed a dusky, cyanotic color (Fig. 4A and B) in many third-degree injuries. None of these cases could walk without severe pain and disability during the three months period observed. All were evacuated to the U.S.A. as unfit for further duty.

In the casualties with cold injuries, ground type, which appeared during the freezing weather in January-February, 1945, the clinical course was identical except edema and blisters were often localized to areas around the great toe. This, of course, has varied considerably, making it impossible to separate the cases clinically except by a history of freezing temperatures.

One severe cold injury of both feet was trapped for five days behind enemy lines and forced to feign death to avoid capture. During this period, he lived in a snow-filled foxhole where his feet became encased in blocks of ice. After five days, he walked and crawled several miles to friendly lines where his shoes were cut off the frozen feet (Fig. 5). This is the only case that required amputation of feet for gangrene. Digits were lost in only one per cent of the 500 carefully followed cases.

The percentage of first, second and third-degree trench foot and cold injuries, ground type, was approximately identical.

* The material studied consisted of 24 biopsies from cases in various stages of the injury and four amputated toes.



FIG. 2-A.—Trench foot, second-degree, early. Right foot shows blister on great toe.

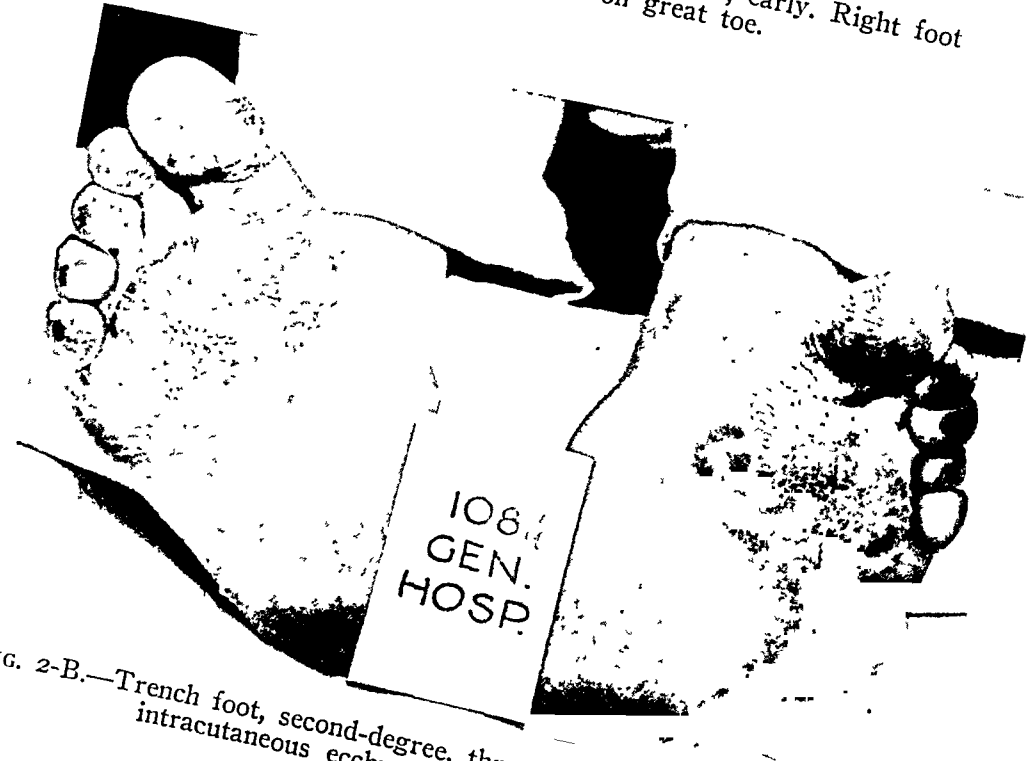



FIG. 2-B.—Trench foot, second-degree, three weeks after exposure showing intracutaneous ecchymosis and early exfoliation.




3-C

3-D

FIG. 3-A.—Trench foot, third-degree, early, acute inflammatory reaction two days after exposure.
3-B.—Same as 3-A, two weeks after exposure, showing edema receding and early mummification of the superficial layers, suggesting impending gangrene.
3-C.—Same as 3-A, four weeks after exposure, showing desquamation of superficial layers of skin.
3-D.—Same as 3-A, six weeks after exposure, delicate skin beneath the mummified superficial epidermis.

## PATHOLOGIC CHANGES IN TRENCH FOOT

In the acute early inflammatory stage, edema, intracutaneous hemorrhage and necrosis was found in the stratum corneum of the skin (Fig. 5). Davis, *et al.*,[5] found the separation of the epidermis from the dermis with a loss of the basal germinal layer in high altitude frost-bite, whereas the basal germinal layer was always intact in the trench foot cases examined (Fig. 6).

Round cell infiltration was present in the perivascular spaces. Suppuration was found only in toes amputated for gross secondary infection. In the late cases (4–6 weeks after exposure) the skin thickness was decreased and sweat glands rare. A proliferation of fibrous tissue was present in the corium and often around nerves. Nerves showed axis cylinder degeneration in early stage and later, evidence of regeneration. The minute vessels showed perivascular round cell infiltration with diapedesis of red blood cells in the severe early cases. Late cases showed thrombosis of terminal arterioles in areas with skin necrosis.

The exact mechanism of the development of skin necrosis after cold injuries is still controversial. Most authors[5, 6, 7] report a true thrombosis of the terminal arterioles and veins, but Kreyberg[3] reports this as a secondary complication. Kreyberg and Rotens[8] have demonstrated patent capillary vessels immediately after experimental freezing. By using a vital dye technic, they showed increasingly capillary permeability through the vessel walls immediately after exposure. As the exposure increased, permeability increased to a degree that all plasma escaped leaving tightly packed blood cells within the lumen of the minute vessels. This "stasis" or "intravascular mass" of blood cells would finally form a mechanical obstruction to blood flow within minutes or hours after the exposure. The area in which stasis develops would later become necrotic. Secondary "true thrombosis" might develop in or about the tissue doomed to necrosis.

This phenomenon has recently been demonstrated by Essex and Quintanilla[10] by direct observation of a peripheral capillary bed after the insertion of transparent chambers in the ears of rabbits. In addition, these authors demonstrated that the stasis was not caused by coagulation since the identical phenomenon was observed in the vessels of animals after their blood had been rendered incoagulable by injections of heparin.

Most clinicians advise slow restoration of blood flow after exposure to cold to avoid stasis and skin necrosis. This viewpoint lacks experimental or clinical confirmation. The recent beneficial results reported by Lange and Boyd[6] in the prevention of skin necrosis by heparinization after freezing may be due to the prevention of secondary true thrombosis developing proximal to the areas of stasis.

## EVACUATION AND CARE OF TRENCH FOOT

The Evacuation and Disposition policy of the First Army and Communication Zone Hospitals are shown in Chart I. Soldiers reporting into

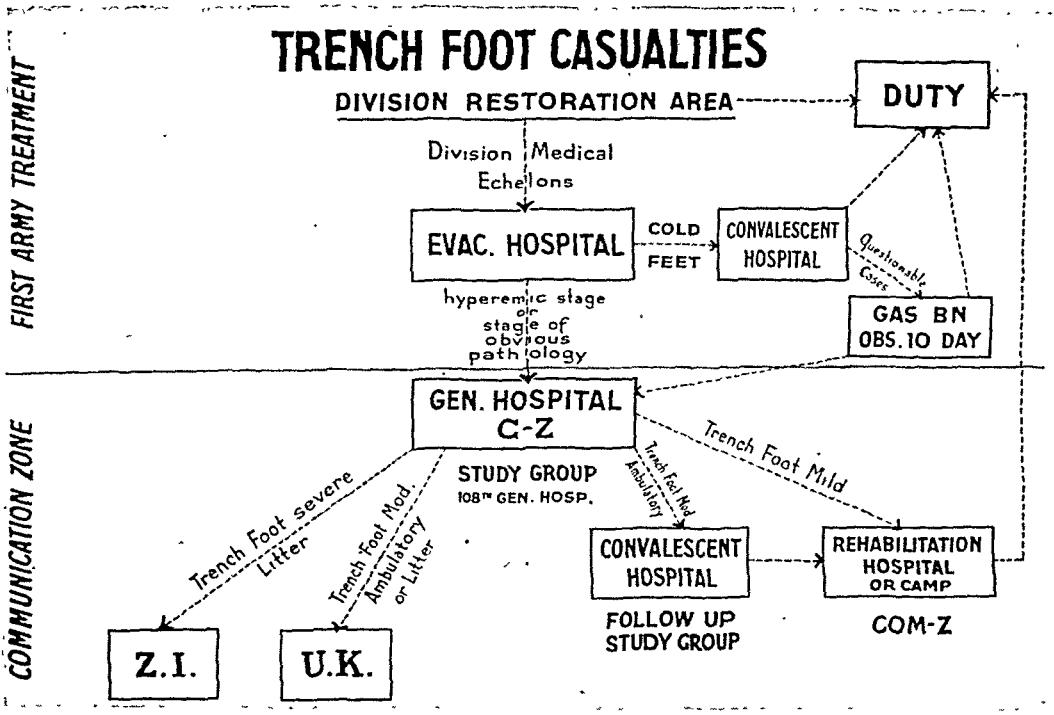



CHART I.—Evacuation and disposition of trench foot casualties E. T. O., 1944–45.

Battalion Aid Stations with "cold feet" should be immediately sent to a nearby "Restoration Area" for at least 24 hours' observation. Experienced clinicians have difficulty in estimating the degree of injury until the reactive hyperemia or inflammatory reaction develops. In the Restoration Area, the *most important point in the evacuation chain,* all "cold feet" should be given a cold foot bath and placed in a cool dry bed. Warm food and drink should be given to restore normal body temperature and gradual, slow restoration of normal blood flow of the feet. External heat, walking or vigorous massage is avoided at this period.

The nurse or doctor should follow the vascular response closely. Simple palpation of the feet at hourly intervals will detect an elevation of skin temperature or a bounding arterial pulse. When these signs of the onset of hyperemia appear, the feet are exposed to a cool environment with the feet elevated on pillows. These measures are favored by clinicians who hold that slow restoration of blood flow will avoid stasis in the capillary bed which subsequently leads to skin necrosis. Pressure bandages over cotton has also been recommended and apparently affords the patient some relief from pain and decreases the edema. After 24 hours of observation, accurate classification of the degree of injury should be accomplished easily. Second- and third-degree injuries are evacuated to General Hospitals where prolonged treatment will be necessary. First-degree injuries, or soldiers escaping without reactions, can be returned to duty after a short rest period. Early accurate diagnosis should avoid the mass evacuation of mild injuries which caused so much

confusion on their arrival at General Hospitals. These cases showed little or no objective evidence of the injury and were often mistaken for malingerers.

Once the hyperemia has developed, the treatment is directed toward preserving the superficial injured layers of epidermis which forms a tough, dry protective covering of the viable layers beneath. The foot is exposed to a cool dry environment, and elevation on pillows continued. The procedure has been likened to the process used in "curing" a ham. The application of



FIG. 4-A FIG. 4-B

FIG. 4-A.—Trench foot, third-degree, two months after exposure. Except for scaling, the feet appear normal.

4-B.—Same as 4-A, showing dusky cyanotic discoloration on dependency. This position causes considerable pain.

ointments, repeated massage or foot baths may produce rents in the protective layer and allow the ingress of secondary infection. The injured layers of epidermis will gradually shed as healing is completed.

*Surgical amputation* should never be done in the early stages except for gross secondary infection. Toes that appear gangrenous may have much viable epidermis beneath the black outer layers. Dry gangrene of the toes occurred in only one per cent of the carefully followed cases. If infection is present, sulfa drugs and penicillin should be used as in any other infection. Tetanus toxoid was given in cases with obvious open wounds. In the vast majority of cases with trench foot, however, the drugs are not necessary.

After the edema has subsided, the treatment is directed toward the prevention of foot deformities caused by atrophy of muscles and the secondary fibrosis which develops. Much difficulty was encountered in the soldiers who were first treated by prolonged bed rest. The resumption of walking or exercise of the feet is often painful. Gentle massage and supervised passive and active exercise as soon as the edema has subsided will prevent this psychologic block from developing. In the mild cases, this therapy is started immediately. It is




FIG. 5.—Cold injury, ground type, third-degree, one month after exposure, showing gangrene of both feet.

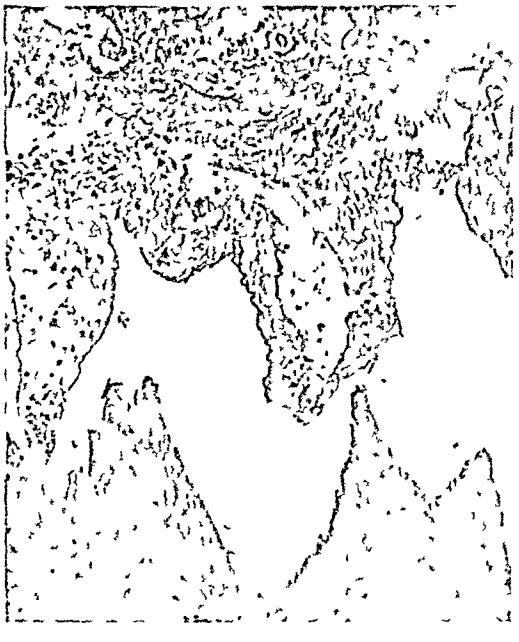


FIG. 6.—Photomicrograph of section from blister in third-degree trench foot. The separation in the epidermis shows the basal germinal layer intact.

important to explain that continued inactivity will produce increasing muscular atrophy, joint stiffness and even permanent disabling contractures of the feet. All first- and second-degree injuries should be offered socks and shoes and encouraged to walk within pain limits at the earliest possible moment. When allowed the privileges of the Post Exchange, movies and American Red Cross, it is surprising how quickly the American soldier will walk without disability.

The use of vasodilator drugs and lumbar sympathetic block was investigated and found to give no relief from pain or decrease the convalescent period in the acute cases under observation.

## SUMMARY AND CONCLUSIONS

1. The extent and causes of the American trench foot casualties during the 1944-45 European Campaign have been presented.

2. A classification of clinical types based on the severity of the injury is presented as used to facilitate rapid disposition of casualties.

3. The pathologic and physiologic changes in trench foot are similar to

frost-bite but less severe. The basal germinal layer of epithelium remains intact in trench foot but is lost in frost-bite.

4. The present accepted methods of evacuation and treatment of trench foot is discussed.

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# WAR-TIME ACTIVITIES OF THE NATIONAL RESEARCH COUNCIL AND THE COMMITTEE ON MEDICAL RESEARCH; WITH PARTICULAR REFERENCE TO TEAM-WORK ON STUDIES OF WOUNDS AND BURNS

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THE MOBILIZATION of civilian research toward meeting the special problems of military medicine and surgery commenced in the spring of 1940, when the Division of Medical Sciences of the National Research Council was requested by the Surgeons-General of the Army and Navy to assemble advisory committees of specialists to aid them in achieving for their respective services the best modern standards of professional practice.

The Committee on Surgery of the National Research Council held its first meeting on June 15, 1940, under the chairmanship of Dr. Evarts Graham. Within the succeeding months there were organized thirteen subcommittees, on Surgical Infections, Neurosurgery, Plastic and Maxillofacial Surgery, Thoracic Surgery, Anesthesia, Radiology, Orthopedic Surgery, Burns, Ophthalmology, Otolaryngology, Physical Therapy, Urology, and Vascular Injuries. The Subcommittee on Surgical Infections and the Subcommittee on Burns were combined in December, 1943 to form the Subcommittee on Infected Wounds and Burns, under the chairmanship of Dr. Allen O. Whipple.

It is the main purpose of this article to review, in broad outline, the program of research which was conducted under the advice and sponsorship of this Subcommittee, not only for the purpose of acknowledging the leadership and inspiration which was provided by its Chairman, but also in order to present to the readers of this journal an historical account of a unique experiment in coöperative surgical research on a national basis. A much fuller account of the work is to be published in conjunction with the History of the Committee on Medical Research of the O. S. R. D. The scientific record of the individual contributions has in large part been published in the surgical literature of the past four years; this account will, therefore, be concerned only with the general aspects of the program of work on wounds and burns and surgical infections, particularly in regard to the background of organization, and the technic of approach. It is hoped that many readers of this journal who were serving throughout the war as medical officers in overseas theaters, and who were necessarily out of contact with the war-time civilian research program, may be interested in knowing something of the method of organization, the difficulties, and the successes, which attended this effort on the home front.

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GENERAL ORGANIZATION OF CIVILIAN MEDICAL RESEARCH

During the period between May, 1940 and August, 1941 the functions of the Committee on Surgery of the N. R. C. and its subcommittees, were limited largely to rendering advice on specialized problems presented to them by the Surgeons-General. It was recognized that the value of some of this advice was limited by the unfamiliarity of most of the Committee members with the special medical aspects of modern warfare, and by the considerable gaps in knowledge which could only be filled by new research. However, no machinery existed to permit the sending of teams of experts to the war theaters where our prospective allies were engaged, and no funds were then available to support the comprehensive program of research which was thought to be required. The problem of funds was solved, however, when President Roosevelt established, in August, 1941, the Committee on Medical Research as a unit of the Office of Scientific Research and Development, and provided it with substantial funds to be employed in research into all phases of military medicine. The Committee on Medical Research immediately requested the National Research Council to serve in an advisory capacity to aid in determining how these funds could best be employed, and the administrative headquarters of the two agencies were established under the same roof in the National Academy—Research Council building in Washington. The membership of the C. M. R. comprised Dr. A. N. Richards, as chairman, Dr. Lewis H. Weed as vice-chairman (Dr. Weed is also Chairman of the Division of Medical Sciences of the N. R. C.), Rear-Admiral Harold W. Smith, representing the Navy, Brig. Gen. James S. Simmons, representing the Army, Dr. R. E. Dyer, representing the Public Health Service, and Doctors A. B. Hastings and A. R. Dochez. This Committee was authorized to make recommendations to the Director of the O. S. R. D., Dr. Vannevar Bush, concerning the expenditure of federal funds for research on problems in the medical field. The funds were made available to each individual investigator through a contract developed between the O. S. R. D. and the institution with which he was associated.

Since the C. M. R. was responsible not only for the initial allocation of funds, but also for the manner in which these funds were spent, it became necessary, as the program expanded, to develop a scientific administrative organization under six main divisions, in Medicine, Surgery, Chemistry, Physiology, Aviation Medicine, and Malaria Studies. The Chiefs and Deputy Chiefs of these Divisions were specialists in the subjects covered by the several divisions and gave major portions of their time to the work of maintaing contact with the investigators, the advisory committees of the N. R. C., and the staffs of the Surgeons-General. The Division Chiefs represented the government as scientific officers on the contracts in their respective divisions.

An hypothetical case will serve best to illustrate the practical operation of the program in its final stage of evolution. Thus, a request by the Army for advice as to the best method of determining the prognosis of frost-bite injury might be transmitted through the National Research Council to the Subcommittee on Vascular Injuries. The problem would be discussed at a meeting of

the group in Washington, with representatives of the Army and Navy and other invited consultants in attendance. Having decided that further research on the problem was needed, the Subcommittee would suggest one or more individuals who might be qualified and prepared to undertake the work; the Chief of the Division of Surgery of the C. M. R. would then approach these individuals, perhaps visiting them in their laboratories in order to determine the adequacy of facilities and their willingness to undertake the work. An application for funds would then be prepared, including a brief description of the plan of attack; this would be transmitted back to the Division Chief, who would refer it to the Subcommittee on Vascular Injuries and the Committee on Surgery if he felt that further advice was necessary; it would then be submitted to the Committee on Medical Research with the final recommendation of the National Research Council and the Division Chief. After the C. M. R. had approved the proposal, the Director of the O. S. R. D. would authorize the initiation of a contract to cover the expenses of the work, including salaries, materials, and overhead costs. The investigator was expected to submit bimonthly progress reports to the C. M. R., and these would be further distributed to the N. R. C. committees concerned, to other interested investigators, and to the armed Services. The investigator might be requested to come to Washington at intervals to make direct reports on his work in conference with other specialists in the field, and to learn of other related work in progress. Finally, when his work had reached a definitive conclusion, it would be made the subject of a formal recommendation from the N. R. C. to the Surgeons-General; who would then decide whether or not the recommendation should be adopted in military practice, and made the subject of a final recommendation to the Surgeons of the respective Service Commands and Theaters. This procedure was undoubtedly time-consuming and cumbersome; to some extent it was developed through historical evolution rather than deliberate design; however, it usually afforded maximum latitude to the investigator in the planning and conduct of the actual work in the designated subject; it provided a necessary measure of advice and coördination by experienced leaders in the general field; and it satisfied the stringent legal requirements regarding the expenditure of public funds by private institutions. The investigator was expected to adhere to the subject of the contract in the conduct of his work, but the subjects were usually capable of broad definition, and allowed the investigator to employ initiative and originality in his work.

A total of one hundred contracts were developed for work in the surgical field—representing total allocations of almost $3,000,000, some of which was not spent. About one-half of this sum was appropriated for work on the prevention and treatment of infections in wounds and on burns. The remainder was divided almost equally between neurosurgical problems and research in the other surgical specialties.

FUNCTIONS OF THE N.R.C. COMMITTEES

Some of the N. R. C. committees functioned more actively than others, owing to the great variations in the scope of the tasks assigned to them. Between meetings the business of the committees was conducted by correspondence and by telephone. Meetings were held at irregular intervals, depending upon the urgency of matters under consideration, but, in most cases, several times a year. The three main functions served by these committees were:

1. To provide opportunities for informal exchange of experience between men with similar problems and interests from civil life and from the armed Services.

2. To draft formal recommendations upon request of the armed forces or other governmental agencies.

3. To sponsor and review proposals for contract submitted to the Committee on Medical Research.

The Committee on Surgery held sixteen meetings, the Subcommittee on Surgical Infections held twenty-one meetings prior to December, 1943, when it was merged with the Subcommittee on Burns; the latter group met eleven times prior to the merger, and the combined Subcommittee held ten meetings. Dr. Frank L. Meleney was chairman of the original Subcommittee on Surgical Infections and gave unstintingly of his time and energy in leading the work of this group during the period of active investigation of the use of sulfonamides in the prevention of infections in accidental wounds. As stated previously, Doctor Whipple, who had served as Chairman of the Subcommittee on Burns, became chairman of the combined Subcommittee on Infected Wounds and Burns in December, 1943, and continued in this capacity until April, 1945, when he was succeeded by Dr. Fred Coller.

In addition to formal meetings of these committees, there were held many *ad hoc* conferences on special subjects which representatives of the surgical committees were requested to attend; these included conferences on shock, blood transfusions and blood substitutes, effects of war gases, surgical manuals, and new hemostatic agents. These conferences brought together representatives of several specialist groups, including internists, physiologists, and biochemists, as well as surgeons. On numerous occasions surgical representatives travelled to Ottawa to attend meetings of the corresponding committees of the National Research Council of Canada, thus, providing a valuable liaison between these groups.

The minutes of all meetings and conferences were recorded in detail, together with abstracts of the scientific papers presented, and were mimeographed and distributed to those who had attended, and to other interested individuals.

The magnitude of the task confronting the administrative and clerical personnel of the National Research Council is reflected in the fact that between May, 1940 and December, 1945 there were held 653 committee meetings and

223 special conferences, attended by a total of 19,760 individuals. In one year alone, the report section of the Division of Medical Sciences edited, mimeographed, and mailed a total of 262,156 copies of 2,718 reports from O. S. R. D.-C. M. R. investigators which required 11,925 stencils and 662,749 sheets of paper![1] The Records Section of the C. M. R. received all progress reports, interim reports, manuscripts for publication, and final reports, gave the necessary clearance whenever security restrictions were involved and distributed to all investigators and to the medical services of the Army and Navy a weekly bulletin containing abstracts of the reports received. There can be no doubt that the medical research program had its share in contributing to the general shortage of paper! It should also be remarked that those who labored on this aspect of war-time research made a contribution of the greatest importance. Without this editorial and information service the organizations could not have functioned because the usual channels of medical information could not have begun to meet the need for the rapid exchange of information required.

The members and administrative officers of the C. M. R. maintained offices in Washington, giving to government service the first claim upon their time, but in many cases continuing to carry part-time responsibilities in their home institutions. Valuable assistance was rendered by a number of technical aides, who gave up their regular professional work in order to devote full-time to government service.

## SUBJECTS OF C.M.R. CONTRACTS IN THE SURGICAL FIELD

The distribution of the O. S. R. D.-C. M. R. contracts exclusively in the surgical field is shown in Table I.

TABLE I

| | No. of Contracts |
|---|---|
| Prevention and Treatment of Surgical Infections | 26 |
| (Of these, seventeen were primarily concerned with patients and nine were primarily laboratory investigations) | |
| Studies on the Pathologic Physiology and Treatment of Burns | 19 |
| (Of these, eleven were primarily concerned with patients and eight were primarily laboratory investigations) | |
| Statistical Analysis of Wound and Burn Studies | 1 |
| Orthopedic Problems and Prosthetic Devices | 8 |
| Cold Injury (including frost-bite and trench foot) | 6 |
| Anesthesia and Pulmonary Physiology | 2 |
| Peripheral Nerve Repair | 14 |
| Concussion | 10 |
| (Of these, six were primarily concerned with patients and four were primarily laboratory studies) | |
| Absorbable Hemostatic Cellulose | 1 |
| Collagen Sutures | 2 |
| Wound Ballistics | 2 |
| Plastic Surgery | 1 |
| Ophthalmology | 4 |
| Radiology | 2 |
| Vascular Surgery | 21 |
| Protein Loss in Lung Surgery | 1 |
| | 100 |

This list by no means includes all of the contracts which had a bearing on surgical problems, but represents only those which were assigned for administrative purposes to the Division of Surgery of the C. M. R., most of them having been recommended to the C. M. R. by the Committee on Surgery and its Subcommittees. The very extensive research programs on shock, blood, and blood substitutes were developed through special committees of the N. R. C., comprising representatives of several branches of medical science, and were administered through the Division of Physiology of the C. M. R. The work on blood-fractionation products, including fibrin foam, fibrin film, and thrombin was sponsored by these groups. Still another committee was concerned with problems of convalescence and rehabilitation, and promoted a large amount of work on the nutritional problems of surgical patients. Work on production and chemical characterization of penicillin was coördinated through a group of chemists and microbiologists, and its clinical investigation was organized and supervised by the Committee on Chemotherapeutics and Other Agents. Naturally, many surgeons participated in the latter study.

It became increasingly apparent that research in surgical problems could not be fitted into a compartmentalized scheme of organization—the solution of most of the fundamental problems of military surgery could only be approached through the coördinated efforts of scientists of virtually every classification.

It would be undesirable to attempt in one article to review all of the work performed through the surgical research program of the National Research Council and the Committee on Medical Research of the O. S. R. D. The interested reader may await publication of the full history of the activities of the C. M. R.—which will include a complete bibliography of the reports published by the individual investigators, and which will be available a few months hence. However, it seems appropriate to enter a somewhat more detailed discussion of one particular phase of the program, the integrated studies which were carried out under the sponsorship of the Subcommittee on Infected Wounds and Burns. This discussion will serve to illustrate the type of coöperative effort which is difficult to achieve in peace-time, largely because of lack of funds, but which was carried out successfully in many lines of research under the impetus of World War II.

### PREVENTION AND TREATMENT OF INFECTION IN WOUNDS AND BURNS

The Subcommittee on Surgical Infections, at its initial meeting on June 6, 1940, began to make plans for a comprehensive study of chemotherapy in the control of infection in wounds. This group collaborated with the Committee on Chemotherapeutics and Other Agents in recommending to the armed services that the prophylactic administration of a sulfonamide by mouth be commenced as soon as possible after injury, particularly as a means of preventing hemolytic streptococcic infection. However, the Subcommittee was reluctant to make any recommendation governing the local use of sulfonamides in the treatment of wounds, because there were no data then available to justify this practice. It was hoped that properly controlled studies on this problem might

be completed before the outbreak of hostilities, which then seemed remote. In May, 1941—one year later, there were still no funds available to establish the needed research units, but, in response to an urgent request from the Surgeons-General, the Subcommittee recommended to them that sulfanilamide crystals be employed locally in all wounds during the interval prior to débridement, and again at the time of wound closure. This action was necessarily based solely upon the current trend of opinion of civilian surgeons, among whom a wave of enthusiasm for this procedure had begun to develop. The opportunity partially to test these recommendations in a large scale clinical and laboratory study was provided in the fall of 1941, after the establishment of the O. S. R. D. and the Committee on Medical Research. Final arrangements were then made to establish wound study units in eight teaching hospitals—Presbyterian Hospital, New York, Johns Hopkins Hospital, Baltimore, Charity Hospital, New Orleans, Cincinnati General, Henry Ford Hospital, Detroit, the Detroit Receiving Hospital and the City Hospital of Akron, where a special research unit was established by the University of Pennsylvania. To these was later added a burn-study unit at the Cook County Hospital, in Chicago. Each unit was equipped with laboratory facilities and personnel for bacteriologic and other clinical laboratory work on the patients under study; in each unit there was a responsible investigator and one or more clinical assistants, who examined all of the accident cases upon admission, observed their primary surgical treatment, directed the chemotherapeutic treatment and the bacteriologic studies, and compiled very detailed records of each case on special forms supplied to all of the units. These records were then submitted to the central statistical office of the project which was maintained under Doctor Meleney's direction in New York. The assessment of the end-results as far as infection was concerned was based on *clinical* rather than *bacteriologic* evidence of infection in the wound. The compilation of complete bacteriologic data on each wound was made simply for the purpose of attempting to relate the end-results of chemotherapy to the bacterial flora of the wound, and to find out what changes in flora might be taking place during the course of treatment. The responsible investigators and their clinical assistants met in Washington with the Subcommittee at intervals of about two months to present the results from their respective units and to discuss the implications of their experiences. Several methods of chemotherapeutic management were evaluated in each of the three main categories of lesions under study, soft-part wounds, compound fractures and burns. One group of patients in each unit received sulfadiazine systemically and a mixture of equal parts of sulfanilamide and sulfadiazine locally; another group received systemic sulfadiazine and sulfanilamide locally; still another received only the systemic drug. Finally, and very fortunately, there was a group which was given only the same standardized surgical treatment provided to all of the patients, and no chemotherapy, either systemically or locally.

By the end of 1942, after one year of operation of the wound study units, something over 1,000 completely studied cases were on file. The analysis of

this material, which has been reported in detail,[2] brought out the following facts:

1. Factors tending to delay or interfere with wound repair, such as extensive tissue trauma, incomplete débridement, or improper or ill-advised closure with tension, residual dead-space, or implantation of foreign materials, will always predispose to the development of infection in accidental wounds.

2. The use of chemotherapeutic agents in any combination and by any route does not prevent local infection of the wound when these predisposing factors exist.

3. Chemotherapeutic agents are probably of great value in preventing invasive sepsis and death from infection following accidental wounds.

In the interest of completeness the study of contaminated wounds was continued in some of the units for approximately one more year, and several new categories of prophylaxis were added, including local sulfathiazole, and systemic penicillin. However, the final report[3] does not offer any essential modification of the conclusions reached after the initial year. It is of interest that the collected experience from all the groups served only to fortify the impressions reached independently by the investigators on the basis of their individual experiences. The Subcommittee brought together individuals of widely differing points of view regarding the problem under study. Many hours were spent in discussion and brisk arguments over questions such as the significance of the statistical aspects of a study in which so many variables were involved, or the number of different categories of treatment which it would be feasible to employ; over how a wound should be cleansed or débrided, and what constituted suitable conditions for primary closure of a wound. However, the series of cases became large enough to permit statistical demonstration of adequate degrees of similarity between the respective treatment groups, and differences of opinion which were not resolved through increasing experience and accumulation of data were found to be essentially without importance.

In spite of the unequivocal results obtained in this study, the Subcommittee was reluctant to recommend to the armed services the complete abandonment of prophylactic chemotherapy. There was little evidence forthcoming from the combat areas to suggest that the local implantation of sulfonamides was harmful, apart from the danger of misplaced confidence in "magic drugs," with resulting compromises in adequacy and timing of surgical treatment. It is true that there were occasional reports of severe urinary tract complications from the administration of sulfadiazine. However, it was recognized that the factor of delay in treatment of civilian accident cases was far less important than the same factor under military combat conditions—and it seemed possible that prophylactic chemotherapy administered to the casualty during transport to a forward surgical unit might possess a measure of value not necessarily demonstrable in the civilian experiment. Therefore, the data from the study were made fully available to the Surgeons-General, and the final decision was left to them as to future military policy in regard to prophylactic chemotherapy under combat conditions. The following quotation from the section on

"Chemotherapy" in the most recent bulletin on wound management from the Office of the Surgeon-General, U. S. A.,[4] indicates that the final evaluation of prophylactic chemotherapy under combat conditions was not dissimilar from that gained through the civilian study:

*"Chemotherapy:* No presently available chemotherapeutic agent can sterilize a contaminated or infected war wound. Neither penicillin nor the sulfonamides can prevent the ultimate septic decomposition of dead tissue or contaminated blood clots. Sulfonamides administered systemically are effective in the prevention and control of invasive hemolytic streptococcal infection but are ineffective in the control of staphylococcal or invasive clostridial infections. Penicillin is effective against hemolytic streptococci and staphylococci and, in addition, prevents the spread of clostridial infection from a focus of affected tissue. The effectiveness and limitations of chemotherapy are established sufficiently to attribute poor results to errors in surgical technic or judgment rather than to drug failures.

(a) "The concomitant use of sulfonamides and penicillin is unnecessary. The use of sulfonamides as a supplement to penicillin therapy contributes only the risk of untoward reactions and complications. There is no clinical evidence of synergism with the two agents.

(b) "The routine local use of chemotherapeutic agents has been abandoned. Penicillin may be instilled into serous cavities or major joints to complement the initial or subsequent surgical management of injuries in these regions. Repeated dressings solely for the purpose of application of antibacterial agents contribute to persistent wound suppuration with aerobic wound pathogens.

(c) "Systemic chemotherapy is an adjuvant to the surgical management of a contaminated or infected wound. It does not offset the hazard of residual dead space or improper drainage."

It is of interest that the conclusions derived from experience of medical officers in war theaters should have so closely paralleled the results of the study in civilian practice.

### EVALUATION OF PENICILLIN IN ESTABLISHED SURGICAL INFECTIONS

During the second year of the operation of the wound study units there was a gradual transfer of emphasis from the problem of prevention of infection in accidental wounds to the problem of *treatment* of established infections, using the same research facilities and personnel, but with the addition of special units at the Boston City Hospital, Cook County Hospital, in Chicago, the Hospital for Joint Diseases, in New York, and the University of California Hospital, in San Francisco. It had become apparent that one important reason for the ineffectiveness of sulfonamides in wound prophylaxis was the relative resistance of the *Staphylococcus aureus* to the action of these drugs. By January of 1943 the supply of penicillin available for clinical research had reached levels which permitted large scale investigation, and adequate quantities were made available to each of the study units. Arrangements were made between the Committee on Medical Research and the Medical Department of the Army to permit the establishment of a special unit to investigate the use of penicillin in connection with the treatment of ununited infected compound fractures at the Bushnell General Hospital, under the direction of Dr. Champ Lyons, a

member of the Subcommittee on Surgical Infections. After an encouraging preliminary experience, a much larger unit was developed by the Army in the Halloran General Hospital, also under the direction of Major Lyons, and large numbers of suitable cases were sent for treatment at this Center. As a result of this highly successful venture in Army research the basic principles governing the usefulness and limitations of penicillin in treatment of infected compound fractures were formulated, and attention was called to the importance of metabolic and nutritional derangement in patients with chronic sepsis.[5]

At about the same time, Dr. Allen O. Whipple was despatched by the Committee on Medical Research to visit the North African Theater and Great Britain, in order to obtain information regarding the preliminary investigations on penicillin in war wounds which were then in progress, chiefly at the hands of British investigators. In the report which Doctor Whipple submitted upon his return, he described the difficulties involved in conducting properly controlled studies within a military Theater, but stated that penicillin could unquestionably be expected to increase the scope and effectiveness of surgery in treating compound fractures, and urged the mass production of the drug. It was pointed out that the saving of mortality and morbidity would amply justify the use of the large amounts of penicillin required for pre- and postoperative treatment of the more serious cases. There is no doubt that this report of Doctor Whipple, transmitted through the C. M. R. to the War Production Board and the penicillin manufacturers, played an important part in stimulating penicillin production to the point where ample supplies were available for treatment of casualties occurring in the invasion of Normandy, nine months later.

Meanwhile, the civilian research units continued to gather experience in the use of penicillin in the treatment of all types of surgical infections, including staphylococcic bacteremia and acute and chronic osteomyelitis, empyema, meningitis, and related disorders. A full abstract of each patient treated was sent to Dr. Chester S. Keefer, of Boston, who directed the civilian research program on penicillin for the Committee on Medical Research and the National Research Council. The experiences of each study unit were presented for discussion at bimonthly meetings of the Subcommittee on Surgical Infections. The result of this collaborative effort was that, by the time penicillin could be made generally available for civilian use, the general principles regarding selection of cases, dosage, indications for combined surgical treatment, and the limitations of the drug, could be published for the guidance of the medical profession.[6]

### TREATMENT OF BURNS

The evolution of burn treatment during the war saw the gradual abandonment of tanning methods and the substitution of a local treatment consisting in the application of a bland padded pressure dressing. An important chapter in the surgical research program under the C. M. R. and the N. R. C. is the story of its part in furthering this trend, which showed itself in military as well

as in civilian surgery. Soon after Pearl Harbor it was recognized by both Army and Navy that tanning methods were poorly adapted for use under military conditions. However, the choice of alternative methods was difficult to make, so many and varied were the technics advocated by different individuals—ranging from sulfonamide films, ointments, and powders, to paraffine sprays and Bunyan bags. This was the problem which was presented to the Subcommittee on Burns, when it was organized under Doctor Whipple's chairmanship in July, 1942. By that time the wound study units of the Subcommittee on Surgical Infections had been in operation for several months, and a large number of burn cases had been treated by a variety of methods, including tannic acid. It had been recognized that tanned burns showed a high incidence of infection, and that such infections were in no way prevented by the use of prophylactic sulfonamides. The severity and chronicity of infections in burns was found to be largely related to the extent of the areas of full-thickness injury and serious infections were infrequent in second degree burns treated by other than tanning methods. This experience was made available to the Subcommittee on Burns. The facilities of the wound study units were offered to the Committee for service as testing Centers for whatever new forms of treatment it might recommend for trial. This close collaboration led ultimately to the merging of the two Subcommittees in December, 1943, with Doctor Whipple becoming chairman of the combined group.

As soon as the unsuitability of tanning methods for treatment of burn casualties of warfare became clearly demonstrated, the Subcommittee recommended to the Surgeons-General in October, 1942, that tanning of burns be discontinued and that procurement of tannic acid preparations be stopped. Although they were not yet prepared to suggest an alternative method, the group had been impressed with the results obtained by Doctor Sumner Koch, and his colleagues, with the use of padded pressure dressings, and by the soundness of the theoretic principle of treating the burn like any other large open wound.[6]

The Boston Cocoanut Grove Fire, in November, 1942, then provided an opportunity dramatically to demonstrate the practical usefulness of this method in handling large numbers of burn casualties. Many valuable data on burns were gathered by the burn-study units at the Massachusetts General and Boston City Hospitals. The Subcommittee on Burns thus felt justified, early in 1943, in recommending that petrolatum gauze and padded pressure dressings be employed in definitive treatment of burns, and, as far as possible, in first aid management as well. They suggested that chemotherapeutic agents might be administered systemically as a means of controlling invasive infections—but the local application of sulfonamides was not recommended as a routine measure in fresh burns.

During the ensuing months much attention was given to the choice of the most suitable materials for direct application to the burned area beneath the pressure dressing. Several types of bland greases and emulsions, zinc peroxide ointment, penicillin and sulfonamide ointments, dry gauze, nylon and rayon

fabric—all were tested—both on clinical burns and on experimental donor-sites. It cannot be said that unanimous agreement was ever attained on the choice of the best local agent—but the very persistence of disagreement among individuals continuously associated in this study was a fairly convincing demonstration that the main consideration was *"nihil nisi bonum"*—and that in the *second-degree burn*, the choice among any of several *harmless* materials was unimportant. It may be said, however, that the usefulness of local sulfonamide was never clearly demonstrated.

Agreement to this extent permitted directing attention more specifically at the problem of local treatment of the full-thickness burn. The worst infections, the most prolonged morbidity, and the most severe instances of nutritional deficiencies were always associated with burns showing extensive third-degree involvement.

The approach to this phase of the burn problem followed two lines—first, the attempt at early surgical excision of the burn slough—and second, the development of chemical methods of hastening the separation of irreversibly damaged skin. Surgical excision and grafting proved feasible if the burn was of limited extent, and if ample quantities of blood were transfused into the patient at the time of the operation. However, the most promising technic for general use in third-degree burns appeared to be the employment of dressings of pyruvic acid in starch paste. This method reached a practical stage of development too late to be employed in the treatment of burns in military hospitals, but it stands as an advance which will be carried forward into civilian practice. When the burn slough can be entirely removed within ten or twelve days of the injury, as is frequently possible with this method, complete coverage with skin grafts can be performed at once, the prolonged phase of suppuration and protein loss is avoided, the further destruction of islands of epithelium through infection is prevented, and the development of scar tissue and contractures is minimized.

The scope of this review will not permit any discussion of the large amount of work which was carried out in many centers on the physiologic aspects of burn treatment—studies which provided both description, and appropriate treatment, of the imbalances in fluid, electrolytes, plasma protein, hemoglobin, nitrogen, and vitamins which accompany the severe burn. Responsibility for work on this aspect of burns was shared with the groups which were primarily concerned with research on shock, blood substitutes, and nutrition.

A valuable opportunity for a large scale demonstration of the soundness of the principles evolved from this collaborative program on burns was permitted at the time of the Hartford circus fire, in July, 1944, when the staff of the Hartford Hospital cordially invited representatives of the Subcommittee on Infected Wounds and Burns to visit their emergency burn wards, and to offer advice concerning the regimen to be employed. It is probably significant that only three deaths occurred among the fifty-four severely burned patients admitted to the Hartford Hospital the evening of the fire. Much credit for this achievement must be assigned to the splendid way in which the hospital staff

was organized to handle such a catastrophe, and to the promptness and efficiency with which shock was combatted with plasma and whole blood.

### OTHER SURGICAL RESEARCH PROJECTS

This article has reviewed only those phases of the surgical research program which were collaborative team projects. No attempt will be made to cover the many important studies which were carried on by individual groups. The research on wound ballistics at Princeton, and at Yale, represents an application to the age-old problem of missile wounds the most modern technics of mechanical, optical, and electronic biophysics. The Department of Radiology at the University of Chicago developed and placed on a practical basis devices for controlling automatically the duration of roentgenray exposures so as to yield films of optimal contrast density. At Columbia a team of investigators studied the tissue reactions and the range of usefulness of absorbable cellulose as an hemostatic agent, and still another group produced a relatively simple method for nonsuture anastomosis of blood vessels. The problem of frost-bite injury and trench foot was studied at several institutions, and the pathogenesis and treatment of these lesions was further elucidated. A team of biologists and physicists at Massachusetts Institute of Technology worked for three years on the preparation from purified animal collagen of a highly standardized absorbable suture material, of great promise for future development. The extensive program of research on cerebral concussion, and peripheral nerve repair under the Subcommittee on Neurosurgery, would require a separate article in itself. Finally the problems of the amputee were taken up by a special committee under the National Research Council, with financial support from the C. M. R. This committee first surveyed the entire field of prosthetic devices and then developed sub-contracts for research designed to make available more comfortable and serviceable artificial limbs. This work is now being continued under the National Research Council with combined support from the Veterans Administration and the War Department.

There were unquestionably many mistakes made, and numerous difficulties encountered, which have not been described in this account. Many of the mistakes came about as the result of civilian ignorance of military conditions, and it must be remarked that the war was almost over before the civilian investigators were permitted to become even partially familiar with the details of some of the medical problems in the combat zones. The work of civilian investigators could have been much better focused on the actual problems of the Theater medical officers if there had been opportunity earlier in the war for direct exchange of information between individuals working on similar problems at home and abroad, respectively. Efforts to obtain wide distribution of research progress reports to individual medical officers in the field were never successful. Difficulties arose from the shortage of trained professional and technical personnel and from the fact that most of the investigators were carrying unusually heavy loads of teaching responsibility in addition to their research work. However, most of those who found themselves occupied in the

war-time research program, whether as Committee members, administrators, investigators, or assistants, felt that their tasks in the effort of total war were significant for peace as well as for war, and the record of accomplishment is one to which they may perhaps point with some degree of satisfaction.

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# THE EFFECT OF PENTOTHAL SODIUM ON MEAN ARTERIAL BLOOD PRESSURE IN THE PRESENCE OF HIGH SPINAL CORD PARALYSIS

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IN 1941, Kees[1] reported that spinal anesthesia could be supplemented satisfactorily with pentothal sodium. This and other favorable reports[2, 3, 4] have led to an increasing use of the intravenous barbiturates in conjunction with spinal anesthesia. In view of this, and because another anesthetic agent (ether)[5] is known to act unfavorably on blood pressure when the spinal cord

TABLE I

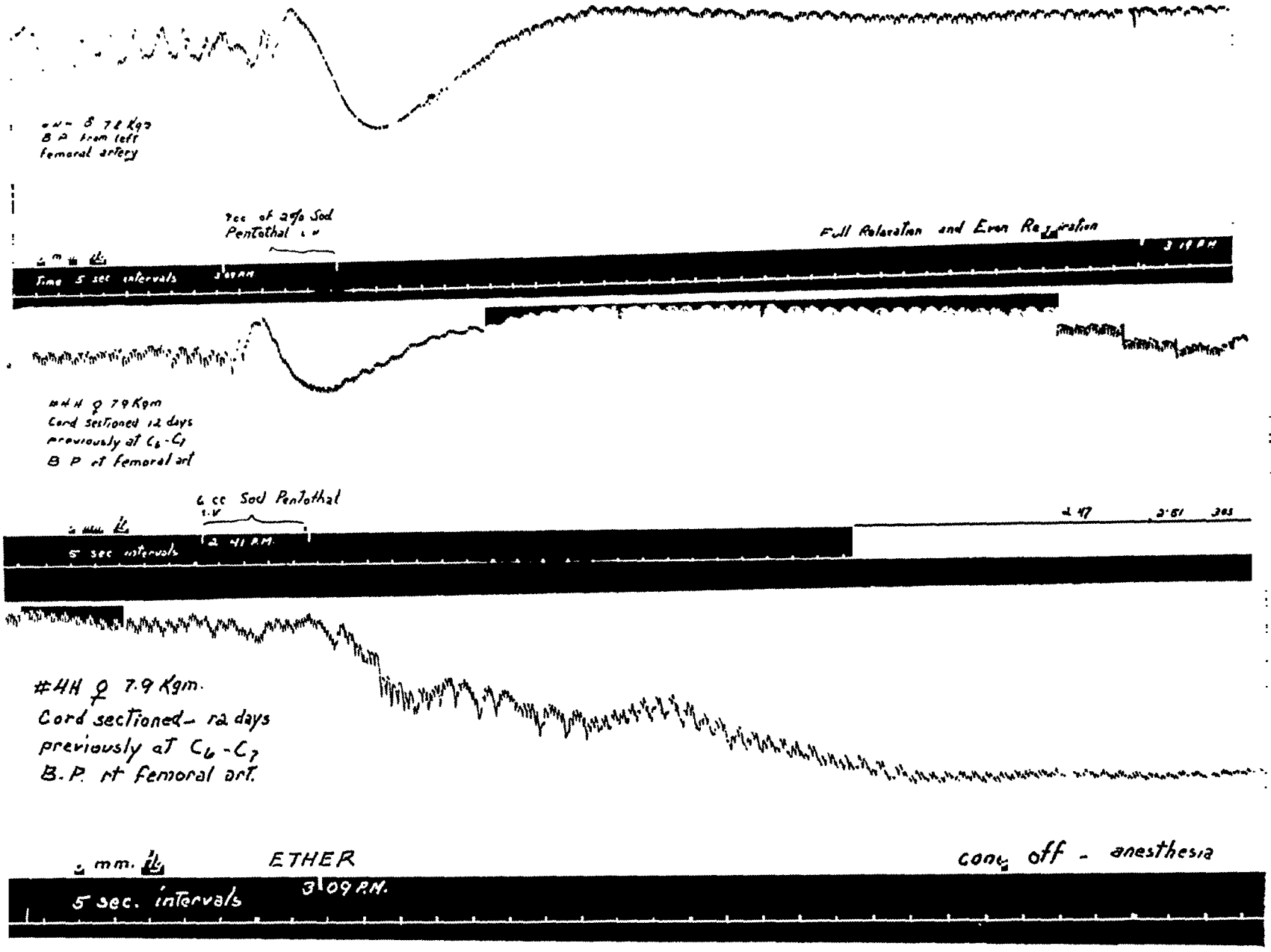
THE MEAN ARTERIAL BLOOD PRESSURE IN THE FEMORAL ARTERIES OF NORMAL AND HIGH SPINAL DOGS AT INTERVALS DURING PENTOTHAL SODIUM ANESTHESIA

| Dog No. | Preanesthetic Level | After 3 Min. of Anesthes. | After 5 Min. of Anesthes. | After 10 Min. of Anesthes. |
|---|---|---|---|---|
| Normals: | | | | |
| 129 | 105 mm. | 140 mm. | 140 mm. | 140 mm. |
| 3 | 115 | 140 | 140 | 140 |
| 4H | 135 | 145 | 140 | 140 |
| 3B | 140 | 170 | 160 | 160 |
| 1 | 120 | 110 | 105 | 105 |
| Spinals: | | | | |
| 129 | 130 mm. | 140 mm. | 130 mm. | 115 mm. |
| 3 | 95 | 115 | 110 | 100 |
| 4H–12th d. | 95 | 115 | 110 | 100 |
| 4H–18th d. | 100 | 100 | 130 | 120 |
| 3B–high sp. anesthes. | 105 | 80 | 95 | 90 |

CHART 1.—This record shows the effect of a fairly rapid injection of pentothal sodium on the femoral arterial blood pressure of a normal dog. With a control blood pressure of 135 mm. Hg, 9 cc. of 2 per cent pentothal sodium was injected in 25 seconds. There was an immediate drop to 85 mm. Hg and a quick return to 145 mm. Hg within 3 minutes after the start of the injection. At 5 and at 10 minutes after the onset of anesthesia the blood pressure registered 140 mm. Hg. A satisfactory anesthesia was obtained for 30 minutes. As has been pointed out in the text, there is no initial fall in pressure when the injection is given more slowly.

CHART 2.—This record shows the effect of a rapid injection of pentothal sodium on the blood pressure of the same dog as in Fig. 1 12 days after aseptic transection of the spinal cord between C6 and C7. With a control blood pressure of 95 mm. Hg, 6 cc. of 2 per cent pentothal sodium was injected in 22 seconds. There was an immediate fall to 75 mm. Hg followed by a quick return to 115 mm. Hg. At 5 and 10 minutes after the onset of anesthesia the blood pressure registered 110 and 100 mm. Hg respectively. The anesthesia lasted 45 minutes. Note the similarity between this record and that of Chart 1.

CHART 3.—This record shows the effect of the inhalation of ether for 1½ minutes on the blood pressure of the same dog as shown in Charts 1 and 2 12 days after spinal cord transection at C6 to C7. The control blood pressure was 105 mm. Hg. Within 1 minute the blood pressure had fallen to 55 and, within 2 minutes to 40 mm. Hg. Previous studies have shown that in such preparations the blood pressure remains low throughout surgical anesthesia with ether. Persistence in the administration of ether in the above case would probably have led to the death of the animal.


CHART 1
Time 5 sec intervals
3 09 P.M.
Full Relaxation and Even Respiration
3 19 P.M.
CHART 2
5 sec intervals
2 41 P.M.
2 47
3 01
3 05
#4H ♀ 7.9 Kgm.
Cord sectioned - 12 days
previously at C6 - C7
B.P. at femoral art.
CHART 3
mm.
ETHER
3 09 P.M.
5 sec. intervals
cone off - anesthesia

impulses are interrupted at D6 or above, it seemed of interest to study the action of pentothal sodium on blood pressure when the suprasegmental impulses have been eliminated high in the spinal cord either by transection or spinal anesthesia.

*Method of Study.*—Control determinations of blood pressure during pentothal sodium anesthesia were made on normal dogs. A cannula was inserted into one of the femoral arteries under 1 per cent novocaine local anesthesia, and the blood pressure was recorded on a kymograph, using a citrate system. Anesthesia was induced with 2 per cent pentothal sodium given in the jugular or the leg veins at variable rates of injection. The depth of narcosis was considered adequate when there was loss of consciousness, complete muscular relaxation, slow, regular respiration and lack of response to painful stimuli. The anesthesias thus administered lasted from 20 minutes to one and one-half hours.

Spinal cord transections were made aseptically in the lower cervical region between C6 and D1. The above experiments were then repeated four to 28 days postoperatively. In one animal, high spinal anesthesia (all intercostal respiration eliminated) with procaine was employed in place of spinal cord transection.

## RESULTS

*Controls.*—In 15 experiments, the initial dose of pentothal sodium required to produce satisfactory anesthesia ranged from 185 to 258 mg. per kilogram of body weight. The rate of injection varied from 0.17 to 0.90 mg. per kilogram, per second, which is somewhat faster than that customarily used in humans. When the injection was rapid, it caused an immediate fall in arterial pressure which in some instances amounted to 70 mm. Hg (Chart 1). When the drug was given more slowly, there was no immediate fall in pressure, and, if given slowly enough to result in an excitement stage, it caused a momentary rise of as much as 60 or 70 mm. Hg. Whatever the initial response, recovery usually occurred within three minutes and the blood pressure remained close to or slightly above the preanesthetic level. When the anesthesia was light, the blood pressure tended to be somewhat elevated. The average control pressure was 117 mm. Hg. and, after 10 minutes of pentothal sodium anesthesia, the average reading was 126 mm. Hg.

*Spinals.*—In five experiments it was found that pentothal sodium may be given in the presence of high spinal cord paralysis without seriously altering the blood pressure (Chart 2). Although the doses of the drug used fell within the range employed on the controls, a smaller amount of pentothal was required in the same dog after high spinal cord transection (Chart 2) or while under high spinal anesthesia. As with the normal animals, a rapid injection produced an initial transitory fall in pressure and a slow injection produced a transitory rise in pressure. The average control pressure in this group was 105 mm. Hg, and, after 10 minutes of anesthesia, the average pressure was again 105 mm. Hg. Sample blood pressure readings from both groups are presented in Table I.

DISCUSSION.—The above experiments on dogs indicate that, when the function of the spinal cord has been interrupted in the lower cervical or upper thoracic region, intravenous pentothal sodium anesthesia produces no serious depression of the blood pressure. Thus, this anesthetic is quite different from ether which is known to cause a pronounced fall in the blood pressure of such animals[5, 6] (Chart 3). Experimentally, then, when the suprasegmental vasomotor control has been eliminated, intravenous pentothal is a safer anesthetic than ether.

## CONCLUSION

Intravenous pentothal sodium anesthesia may be administered to dogs with high spinal cord paralysis without seriously altering the blood pressure. This is in marked contrast with ether anesthesia which, under similar circumstances, produces an abrupt and dangerous fall in blood pressure.

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# THE IMPORTANCE OF WHOLE BLOOD TRANSFUSIONS IN THE MANAGEMENT OF SEVERE BURNS

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RECENT STUDIES in the physiology and treatment of burns have brought forth controversial views in regard to the form of replacement therapy indicated during the immediate as well as the later stages of burns. Riehl,[15] in 1925, advocated whole blood transfusions in the shock phase and in subsequent years many other investigators wrote of its advantages. However, after 1938, plasma or serum was widely accepted as the treatment of choice in burn shock. More recently, oral electrolyte solutions and whole blood transfusions, individually or in combination, have been recommended. The correct answer to the problem probably lies in the integrated use of all three agents, but to determine the amounts and the time at which each should be administered will require the critical evaluation of more extensive laboratory and clinical data. To contribute toward this goal is the purpose of the present communication.

## CLINICAL MATERIAL

The ten cases selected for the present analysis suffered flame burns of from 30 to 80 per cent of their body surfaces and were treated under the direction of various members of the surgical staff of the Presbyterian Hospital, New York, between May 28, 1941 and December 3, 1944. They are not consecutive cases but include only extensive burns treated during that period upon whom sufficient data were obtainable to render them useful for comparative study. The fluid therapy in Case 8 was discussed in a previous paper.[21]

The first four cases had overwhelming burns and from the outset appeared to have little or no hope of survival but are presented as a comparison of four types of shock therapy. Of the remaining six cases, two died in the post-shock phase and four survived. They are presented mainly for the analysis of their supportive treatment during the period of healing. Table I presents a summary of the ten cases analyzed.

## METHODS

Percentages of the burned areas were estimated on the basis of Lund and Browder's[10] modification of the Berkow scale. Blood volume determinations, where referred to, were done by the method of Gregerson under the direction of Dr. Dickinson Richards[14] and his associates who simultaneously studied some of the cases.

In charts of the individual cases the average daily temperature is used as a simple index of the patient's general condition during the course of treatment.

TABLE I

SUMMARY OF CASES

| Case | Sex and Age | Per Cent of Burn | | | Shock Therapy | Post-shock Therapy | Outcome |
|---|---|---|---|---|---|---|---|
| | | Total | 3° | 2° | | | |
| 1 | M—54 | 80 | 60 | 20 | 1500 cc. oral lactate in 4.5 hours | | Death in 4.5 hours |
| 2 | F—45 | 60 | 45 | 15 | (partially vomited) | | Death in 6 hours |
| 3 | F—73 | 30 | 25 | 5 | 2000 cc. serum, 2000 cc. saline, 2000 cc. plasma I.V. in 6 hours; 800 cc. saline I.V. in 15 hours | | Death in 15 hours |
| 4 | F—74 | 75 | 50 | 25 | 1500 cc. oral lactate | 1700 cc. plasma in 4 days | Good recovery from shock; death on the sixth day |
| 5 | F—32 | 42 | 30 | 12 | 1500 cc. blood, 1000 cc. plasma, 3000 cc. saline I.V.; 1500 cc. lactate P.O.; 1000 cc. blood in 36 hours | Small infrequent transfusions: 1800 cc. blood, 1250 cc. red cells in 5 weeks | Good recovery from shock, but progressive anemia and hypoproteinemia with death on the 37th day |
| 6 | F—29 | 44 | 34 | 10 | 3000 cc. plasma, 1500 cc. saline I.V.; Fluids ad. lib. P.O. in 72 hours | Oral R only until 14th day; 3000 cc. blood, 500 cc. red cells in next 11 days | Severe red cell and protein deficits not controlled by late transfusions; death from pulmonary complications on the 25th day |
| 7 | M—25 | 51 | 33 | 18 | 9000 cc. lactate and saline, and 2000 cc. other fluid by mouth in 24 hours; (4300 cc. vomited) | Frequent transfusions: 1300 cc. blood in 8 days, 2500 cc. blood in next month | Post-shock anemia quickly corrected; complete healing in 3.25 months |
| 8 | M—32 | 53 | 7 | 46 | 3500 cc. plasma, 3000 cc. saline I.V. in 6 days | Frequent transfusions: 6500 cc. blood, 2000 cc. plasma in 1 month | Progressive healing: discharged in 4.5 months |
| 9 | F— 9 | 50 | 35 | 15 | 4000 cc. serum, 4500 cc. saline I.V. in 48 hours | Frequent transfusions: 3660 cc. blood, 1460 cc. red cells in 5 weeks | Anemia and hypoproteinemia quickly corrected; complete recovery in five months |
| 10 | F—27 | 50 | 44 | 6 | 900 cc. plasma, 1200 cc. saline I.V. in 3 days; 10,000 cc. plasma, 5,000 cc. glucose I.V. in 5 days; NaCl tablets P.O.—10 Gm./day | Frequent transfusions: 5,500 cc. blood, 500 cc. red cells, 1,100 cc. plasma in 5 weeks | Good healing and recovery from hypoproteinemia after anemia was overcorrected; 8 months in hospitals |

Changes in the plasma protein concentrations and in the hematocrit or erythrocyte counts are recorded. The type and volume of replacement therapy is shown in the form of blocks at the base of the charts. Additional data on the electrolyte intake and output, and plasma electrolyte concentrations on six of the cases were done according to acceptable methods.[20] All patients transfused were given blood of their individual group and the Rh factor was determined for each except in Case 8.

ANALYSIS OF SHOCK THERAPY IN OVERWHELMING BURNS

**Case 1.**—E. J., No. 735714, (Chart I), a 64-year-old Negro garage worker was admitted March 2, 1944, shortly after receiving a burn of 80 per cent of his body surface when his clothing had been ignited by the explosion of a can of gasoline. Intense hemolysis was noted in the initial blood samples. Morphine was given for pain and after a minimal cleansing his wounds were covered with a pressure dressing over a base of ointment gauze. While the dressing was being applied a nasogastric tube was passed and M/6 sodium lactate solution was administered through the tube, *much of which was vomited.* The patient was oriented and rational upon admission with a blood pressure of 150/84 but he soon became restless and then comatose, and died in burn shock four hours after admission. No intravenous therapy was given.

COMMENT.—This case illustrates the usual course of an overwhelming burn in which no effective shock treatment is given. It is noted that the plasma sodium and chloride values were normal at the time of admission and at death, but acidosis was not controlled. The hemoglobinemia and elevated plasma potassium indicate destruction of red cells which probably occurs in and adjacent to the burned area.

**Case 2.**—G. E., No. 692081 (Chart II), a 45-year-old housewife who was extensively burned on November 10, 1942, when her bed clothing caught fire while she was smoking in bed in an intoxicated condition. Sixty per cent of her body surface was involved (Fig. 1) and deep hemolysis was noted in the admission blood samples. A variety of local ointments and pressure dressings were applied to the wounds. Replacement therapy included 2,000 cc. of serum and 2,000 cc. of normal saline by vein within five hours. Hemoconcentration did not occur and blood pressure was maintained. As a fall in hematocrit was noted whole blood was ordered, but before it could be given the patient expired. Autopsy revealed acute pulmonary congestion, edema of the pharynx and epiglottis, and the trachea and bronchi filled with mucinous secretions.

COMMENT.—This patient apparently suffered moderate smoke burns of the upper respiratory passages and death resulted from drowning in her own secretions. The rapid infusion of saline may have been a contributing factor to the edema and hypersecretion found in the respiratory tract at autopsy.

**Case 3.**—C. D., No. 760218, (Chart III), a 73-year-old chronically ill white woman who was admitted October 12, 1944, shortly after suffering a deep burn of the right side of her body. She had been smoking in bed while intoxicated and the bed clothing had been ignited by a cigarette held in her right hand. Being unable to move because of severe arthritis she was exposed to the flames for several minutes before help arrived. The burned flesh was charred and deeply indurated (Fig. 2). Initial blood samples showed intense hemolysis and the admission urine obtained by catheter resembled Burgundy wine from hemoglobinuria. An ointment gauze pressure dressing was applied to the wounds, 2,000 cc. of plasma and 800 cc. of normal saline was administered by vein and 1,800 cc. of M/6

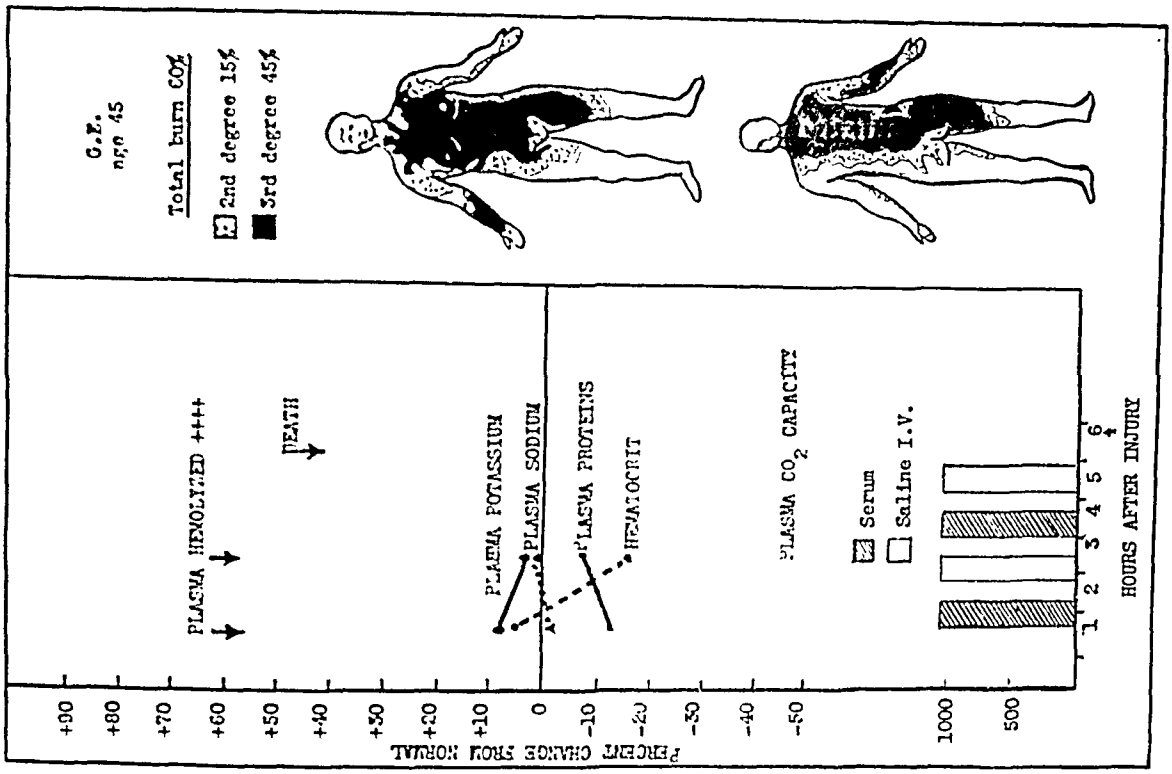



CHART II.—Treatment and course of Case 2.

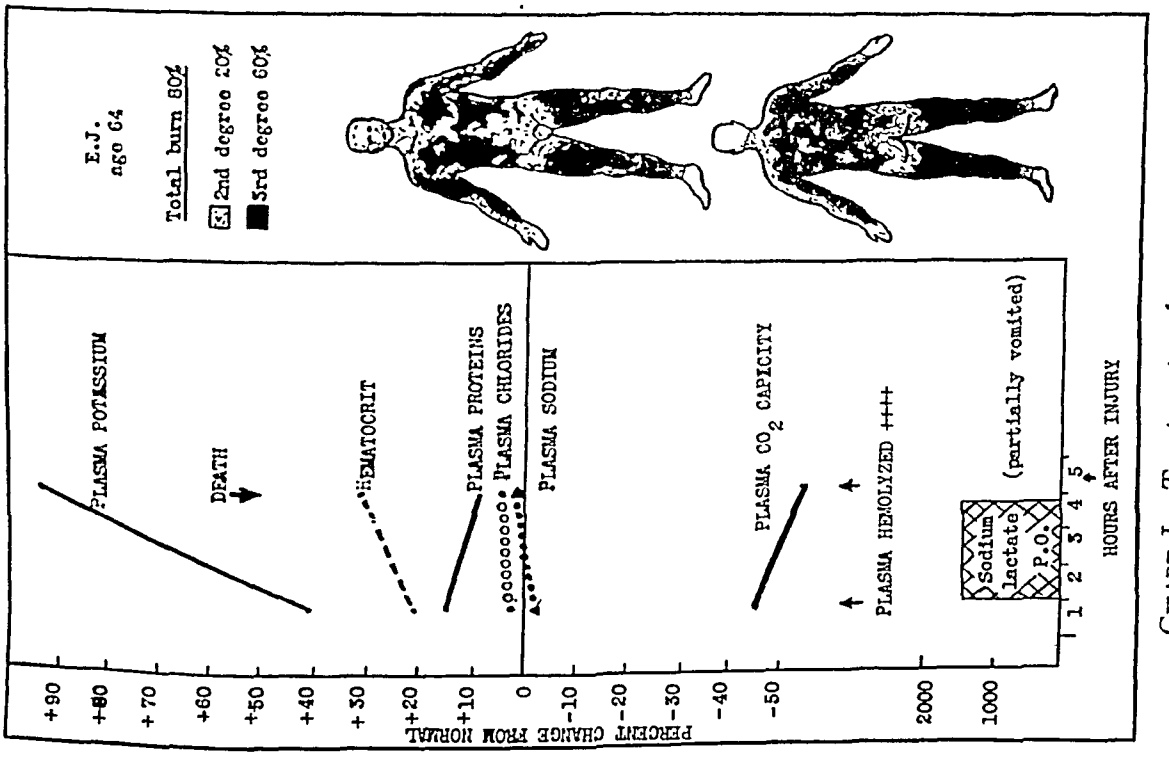



CHART I.—Treatment and course of Case 1.

lactate solution was given by nasogastric tube. No further urine was obtained and the patient expired 14 hours after admission. Additional information revealed she had been a chronic alcoholic, luetic, diabetic, hypertensive and had been confined to her bed for a year.

COMMENT.—Although only 30 per cent of the body surface was involved in this case, the tissue destruction was obviously very deep, and this injury added to her debilitated state was considered an overwhelming insult. Her survival time was comparable to that reported by Moyer, and his associates,[4] for severely burned animals treated with serum by vein and chloride-bicarbonate solution by mouth.

**Case 4.**—L. S., No. 765044, (Chart IV), a 74-year-old housewife was admitted November 27, 1944, shortly after sustaining a flame burn involving 75 per cent of her body surface. Her clothing had been ignited by an accident with cleaning fluid at home. Hemolysis was present in early blood samples. Morphine was given for pain, and the wounds were hastily cleansed of loose débris and covered with an ointment gauze pressure dressing. Replacement therapy during the first 12 hours included 1,000 cc. of whole blood, 500 cc. of plasma and 1,150 cc. of normal saline by vein and 1,500 cc. of M/6 lactate solution by stomach tube. On the following day an additional 500 cc. of blood, 500 cc. of plasma, 2,000 cc. of normal saline, 300 cc. of 5 per cent saline and 1,000 dog units of eschatin were given by vein and 1,750 cc. of lactate solution by mouth, about 1,000 cc. of which was vomited. The urinary output during the first 36 hours was 740 cc. and thereafter averaged about 1,000 cc. per day until her death on the sixth day. The patient remained rational and surprisingly comfortable for the first five days. She was digitalized because of the threat of cardiac failure. No anemia developed but there was a moderate fall in plasma protein concentration in spite of three additional infusions of plasma. Though no autopsy was obtained, death appeared to result from physiologic exhaustion rather than from the failure of any one specific organ or system.

COMMENT.—The use of whole blood combined with plasma, saline and oral electrolyte solution in the early stages succeeded in prolonging life in this

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FIGS. 1 and 2.—Cases 2 and 3 on admission, each with charred skin burned to a depth of 3 to 4 cm. Blood samples showed intense hemolysis in both cases.

FIGS. 3 and 4.—Case 5: General view on admission and detail of right thigh at time of death 37 days later showing necrosis of the fat and erosion of the wound edges which resulted from inadequate treatment.

FIGS. 5 and 6.—Case 9: Anterior view 16 days after injury and dorsal aspect of trunk wound two weeks later at time of homografting. Large frequent blood transfusions were used throughout this critical period.

FIGS. 7 and 8.—Case 10: Triple dye eschar intact one month after injury, and massive but healthy granulating surface partially covered with homografts ten weeks later; progress occurred only after over-correcting her anemia.





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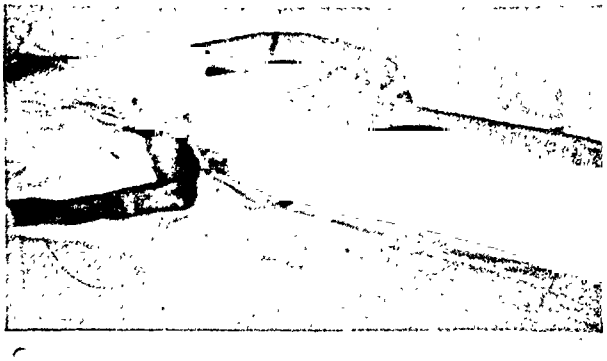


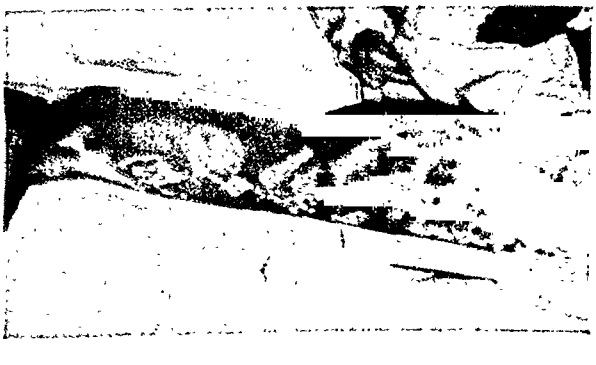
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elderly patient with an overwhelming burn. The acidosis was corrected and anemia was prevented. Treated by other methods burns of this magnitude are usually fatal within 24 hours.

## THE RATIONALE FOR GIVING WHOLE BLOOD TRANSFUSIONS AND ELECTROLYTE SOLUTIONS IN BURN SHOCK

The importance of electrolyte therapy was revived in 1943 by Rosenthal[17] who demonstrated that isotonic sodium chloride solution given orally was more efficient than intravenous plasma in controlling burn shock in mice. In 1944, Fox[7] reported a clinical study of this method using oral sodium lactate solution. In the same year Moyer, Coller, Iob, Vaughan and Marty[12] published the first comprehensive comparative study of the effectiveness of electrolytes, serum and blood, used separately and in various combinations to treat shock in severely burned dogs. Their experiments demonstrated that the combination of blood by vein and a saline-bicarbonate solution by mouth was effective while blood or electrolyte solution alone, or serum in combination with electrolyte failed.

In 1945, Abbott, Meyer, Hirshfeld and Griffin[1] confirmed Moyer's work and demonstrated that the anemia which tends to develop during the convalescent period could be prevented if whole blood was given early. In a clinical evaluation of these principles Abbott, Pilling, Griffin, Hirshfeld and Meyer[2] also concluded that whole blood transfusions plus electrolyte solution by mouth was an effective method of combating burn shock, and that this form of therapy will alleviate the anemia which is usually seen during the period of convalescence.

In a simultaneous report, Evans and Bigger[6] used large amounts of whole blood for treating shock in 32 severely burned patients and found it could be given safely in the presence of marked hemoconcentration, and when given in adequate amounts secondary anemia was regularly avoided. Blood-volume studies by these authors, made soon after the burn, indicate a significant decrease in circulating red cell mass and they feel this accounts for a considerable portion of the anemia which usually appears after burn shock but is masked during the period of hemoconcentration.

Even during the years when plasma or serum was generally used in treating burn shock many clinicians never entirely gave up the use of whole blood and were cognizant of its importance as mentioned in the writings of Harkins,[9] Duval,[5] Scudder,[20] and Brown and McDowell.[4]

The indication for whole blood is to replace blood loss. In shock from severe burns the changes in hemodynamics are equivalent to those of a massive hemorrhage combined with an additional loss of water and electrolytes (dehydration) and are not simply those of a plasma 'leak' as is often assumed. Schievers,[18] in 1936, working with rabbits demonstrated a fall in total blood volume to approximately 50 per cent of normal following a severe burn and pointed out that this deficit included the loss of red cells in almost the same proportion as plasma loss.

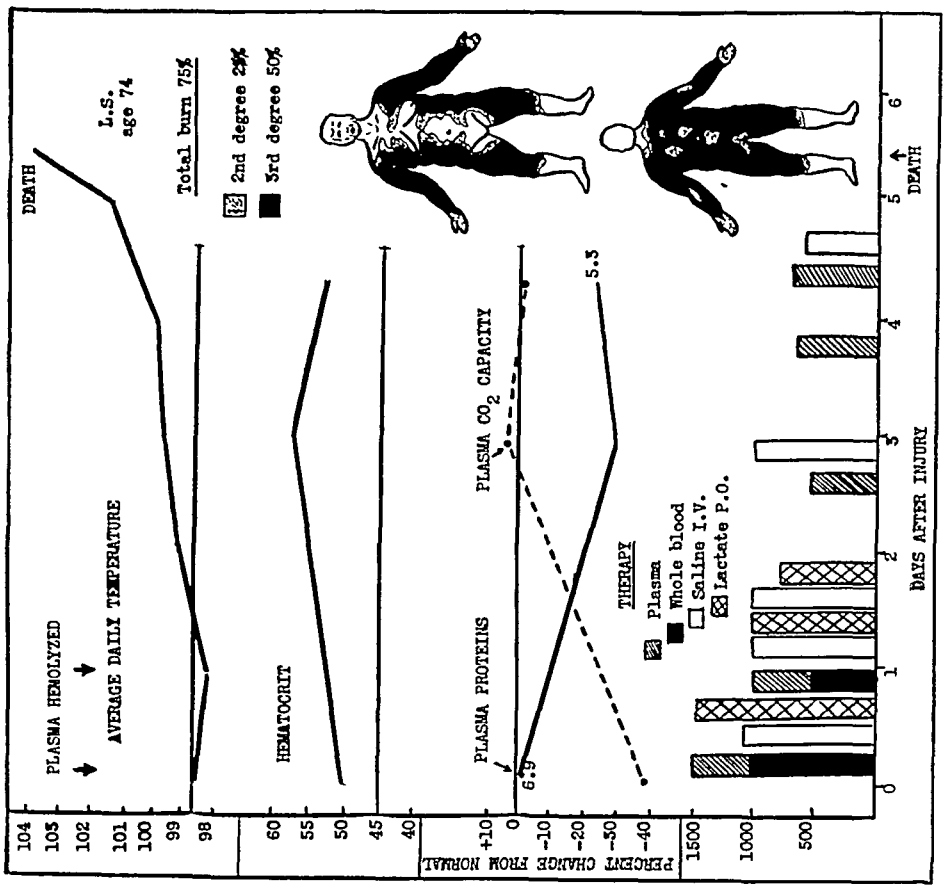



CHART IV.—Treatment and course of Case 4.

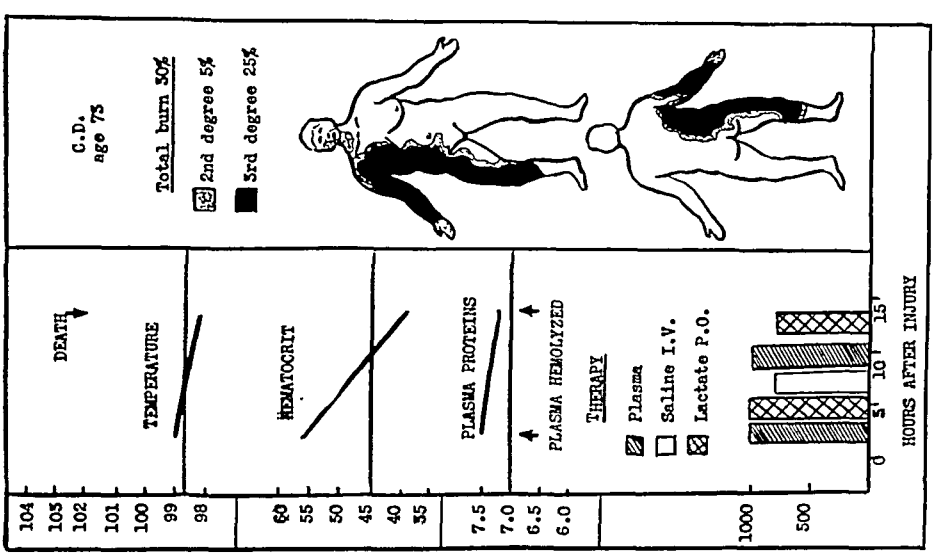



CHART III.—Treatment and course of Case 3.

The mechanism of the loss of red cell mass from the circulation involves a number of causes. The destruction of red cells by heat with liberation of hemoglobin and potassium was demonstrated in 1884 by Von Schjerning who also pointed out the toxic effects of excess potassium in the circulation. Other partially damaged cells may fragment when exposed to the alterations in osmotic pressure which result from changes in water, electrolyte and plasma protein concentrations, thus further contributing to the hemoglobinemia and hemoglobinuria frequently seen early in extensive burns particularly where there has been deep tissue damage.[9] Evans and Bigger[6] believe the erythrocyte loss is due mainly to sludging or trapping of red cells in capillaries in and adjoined the burned tissues. Others[1, 8] have shown that congestion of large and small vessels and small hemorrhages in the damaged areas account for whole blood loss from the circulation. Preëxisting anemia is another factor which may add to the deficit in some cases.

The severity of the blood loss during the early phase of severe burns in patients has been graphically illustrated by Evans and Bigger.[6] The total loss in circulating blood volume estimated in nine of their cases ranged from 1,200 cc. to 2,500 cc. (25 to 50 per cent of the circulating blood volume of the average adult) and the per cent of red cell mass in the fluid lost from the circulation varied from 7 to 55 per cent, with an average of 37.5 per cent. In other words, the average fluid lost from the circulation was equivalent to slightly anemic blood. Assuming a normal hematocrit of 45, and a deficit of red cell mass amounting to 37.5 per cent of the fluid lost from the circulation in a severe burn, one would theoretically have to administer four parts of blood to one part of plasma to restore a normal balance. Since there is a tendency to progressive anemia in burns and since the body has no significant stores of hemoglobin but is able to mobilize considerable reserves of plasma protein, the argument for using whole blood entirely in place of plasma early in severe burns has a sound theoretic basis. Such massive transfusion therapy has been made possible with the advent of blood banks and has been made safer by the elimination of transfusion reactions due to the Rh factor.

The restoration of electrolyte and water losses beyond those not replaced with transfusions can usually be accomplished safely by the oral route provided adequate transfusion therapy is also given. Our clinical observations have been in agreement with the experimental report of Moyer[13] who noted vomiting and delayed gastric emptying as a frequent complication in burn shock, but when shock was controlled by blood transfusions fluids were usually well tolerated by mouth.

Since employing sodium lactate therapy by vein or by mouth during burn shock we have observed three striking beneficial effects: (1) acidosis is more quickly controlled, as reflected by the plasma $CO_2$ capacity; (2) excess potassium is quickly eliminated from the circulation; and (3) urinary output is improved. However, when lactate solution is the only electrolyte given there may be a tendency to overcorrection of the acidosis even to the point of clinical alkalosis, as noted in some of our cases. In such instances the plasma chloride

concentrations tend to fall below normal. These differences in plasma electrolyte changes are graphically illustrated in the two groups of cases compared in Chart XI. It is now generally felt that the electrolyte therapy should include a mixture of lactate and saline, or bicarbonate and saline to more nearly approach the physiologic needs of the patient. Oral administration should be started as soon as vomiting has ceased.

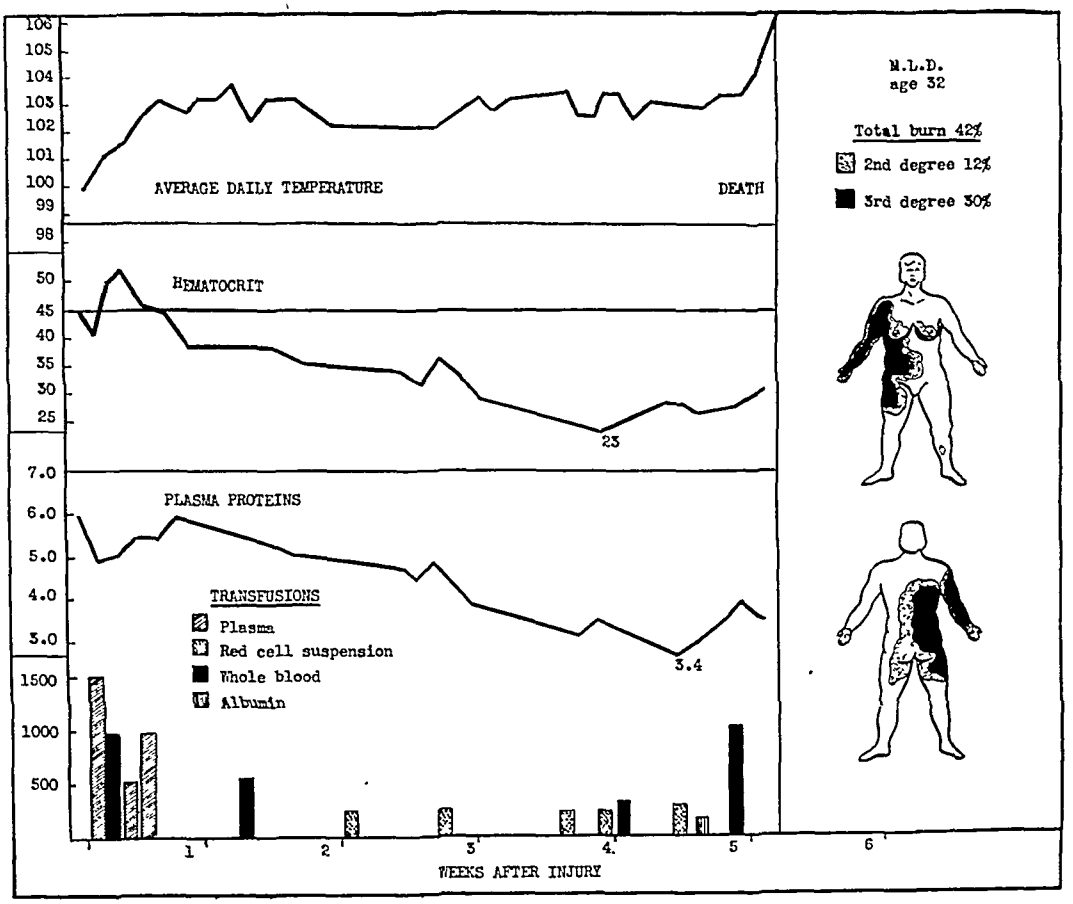



CHART V-a.—Treatment and course of Case 5.

The theoretic advantages of oral treatment alone, as proposed by Rosenthal,[17] are indeed great, but his conclusions were based on experiments on mice, animals which are physiologically unable to vomit and which possess a stomach capable of accommodating 5 per cent of their body weight in fluid (equivalent to three liters of fluid for an adult human). The advocates of oral therapy claim that a continuous drip of electrolyte solution into the stomach is adequate, but even when burn shock can be controlled by this method, the deficit in red cell mass and plasma proteins is *not corrected* as noted in the cases reported by Fox.[7] Such deficits present a serious obstacle to the patient facing the task of healing a large wound as is clearly brought out in Case 6.

## ANALYSIS OF THE REPLACEMENT THERAPY IN THE HEALING STAGE OF SEVERE BURNS

Of the six cases in this group, three received initial treatment in other hospitals and were transferred to us after shock had been controlled. Some deductions may be drawn regarding the effect of early treatment on their later course, but the cases in this group are presented mainly for a comparison of the form of supportive treatment used during the post-shock period.

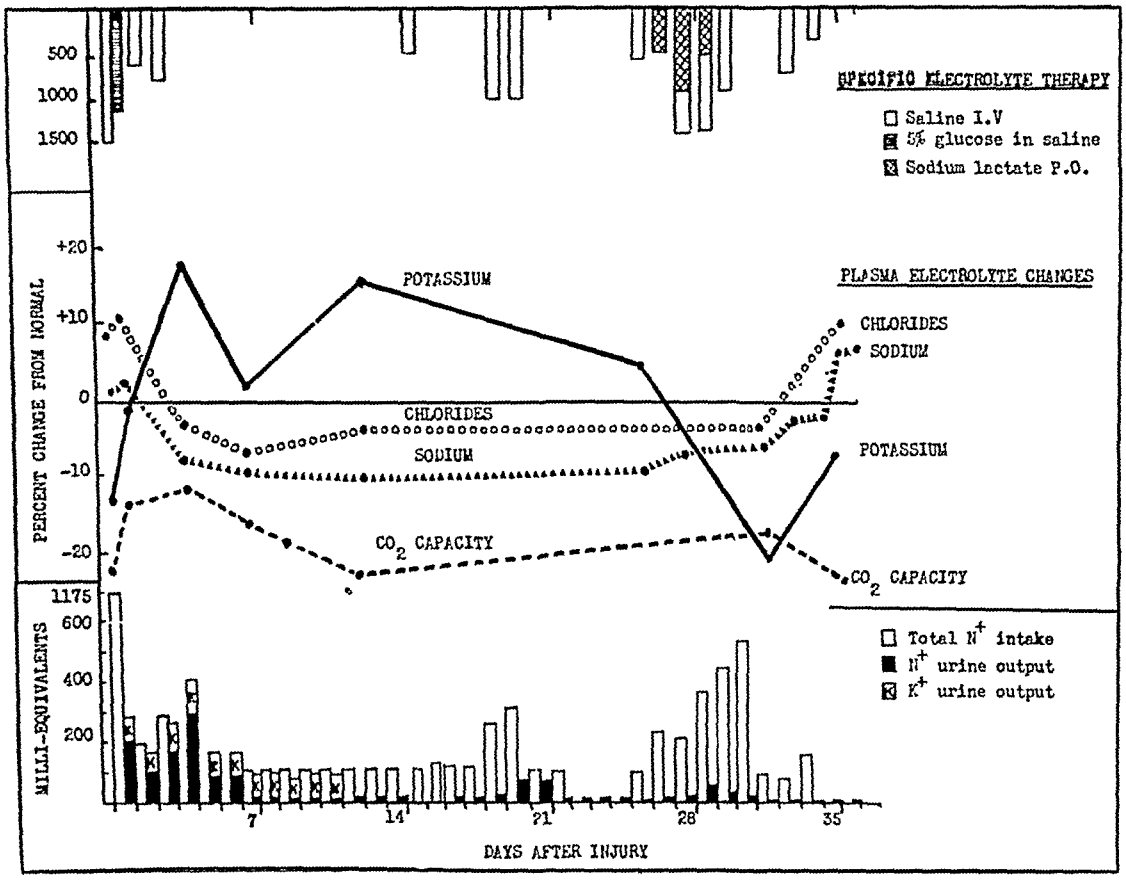



CHART V-b.—Electrolyte intake, output and plasma changes in Case 5.

**Case 5.**—M. L. D., No. 742683 (Chart V), a 32-year-old white woman was admitted, March 14, 1944, shortly after receiving an extensive flame burn of her right arm, trunk, buttocks and right thigh. She had fallen asleep while smoking in bed in an intoxicated condition, with resulting injury to 42 per cent of her body surface. Treatment was carried out under the direction of a combined group interested in the study of burns and shock. The wounds were dressed with a variety of ointment gauzes and an outer pressure dressing. Shock therapy included 1,500 cc. of plasma, 1,000 cc. of whole blood and 1,500 cc. of normal saline intravenously during the first 24 hours. Fluids as desired were allowed by mouth but no specific oral electrolyte therapy was given during the early course of her illness. An additional 1,600 cc. of plasma was injected on the 2nd and 3rd days. Urinary output for the first 24 hours was 1,170 cc. and averaged about 1,500 cc. per day during the ensuing three weeks. The patient's general condition was surprisingly good during the first week and her plasma proteins and hematocrit were near normal until after the first week. A gradual rise in total blood volume due mainly to an increase in plasma volume was noted during the second, third and fourth weeks and it was the feeling of the group directing her therapy that

transfusions might overload her vascular system and precipitate cardiac failure. The small infrequent transfusions given during this period were little more than enough to cover the blood withdrawn for various tests. A progressive clinical decline ensued as reflected by the steady fall in the hematocrit and plasma proteins which reached levels of approximately 50 per cent of normal by the end of the fourth week. Her wounds likewise reflected the inadequacy of the replacement therapy for a progressive destruction of tissue was noted. Areas which early in her course appeared superficially damaged became full thickness in depth and as the slough separated from the more deeply burned regions progressive necrosis of the underlying fat was observed (Fig.

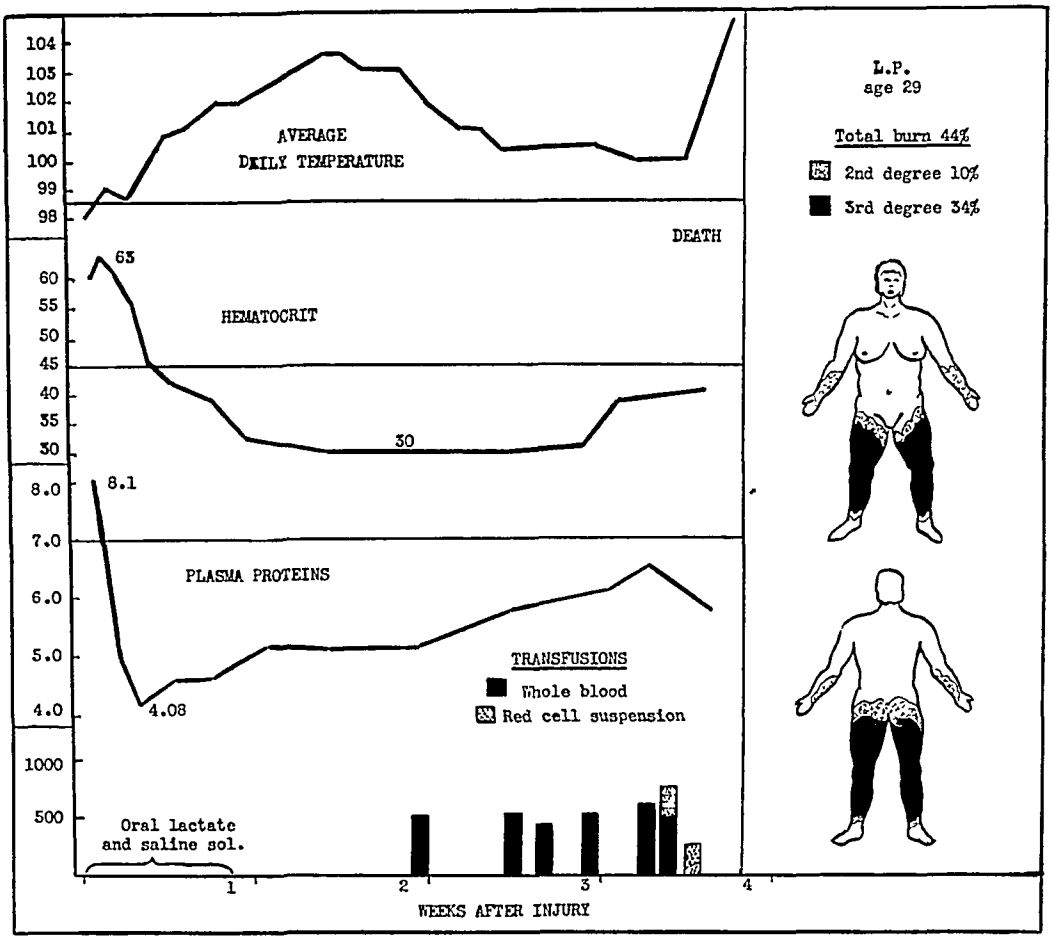



CHART VI-a.—Treatment and course of Case 6.

4). An abortive effort was made to replace her blood deficits during the fifth week, including the administration of oral lactate solution, but by this time she was too exhausted and her pathology too extensive to prevent her death which occurred on the 37th day. Postmortem examination revealed anasarca, pulmonary edema, lipid depletion of the adrenals and destruction of 42 per cent of her skin surface.

COMMENT.—The use of whole blood and plasma for the treatment of shock in this case was successful but the supportive therapy later in her course was obviously inadequate, having been withheld for the reason mentioned above.

The forcing of electrolytes late in her course, when anemia and hypoproteinemia were severe, was probably ill-advised for raising her plasma sodium and chloride levels to above normal (Chart V-b) may have contributed to the anasarca and pulmonary edema found at autopsy.

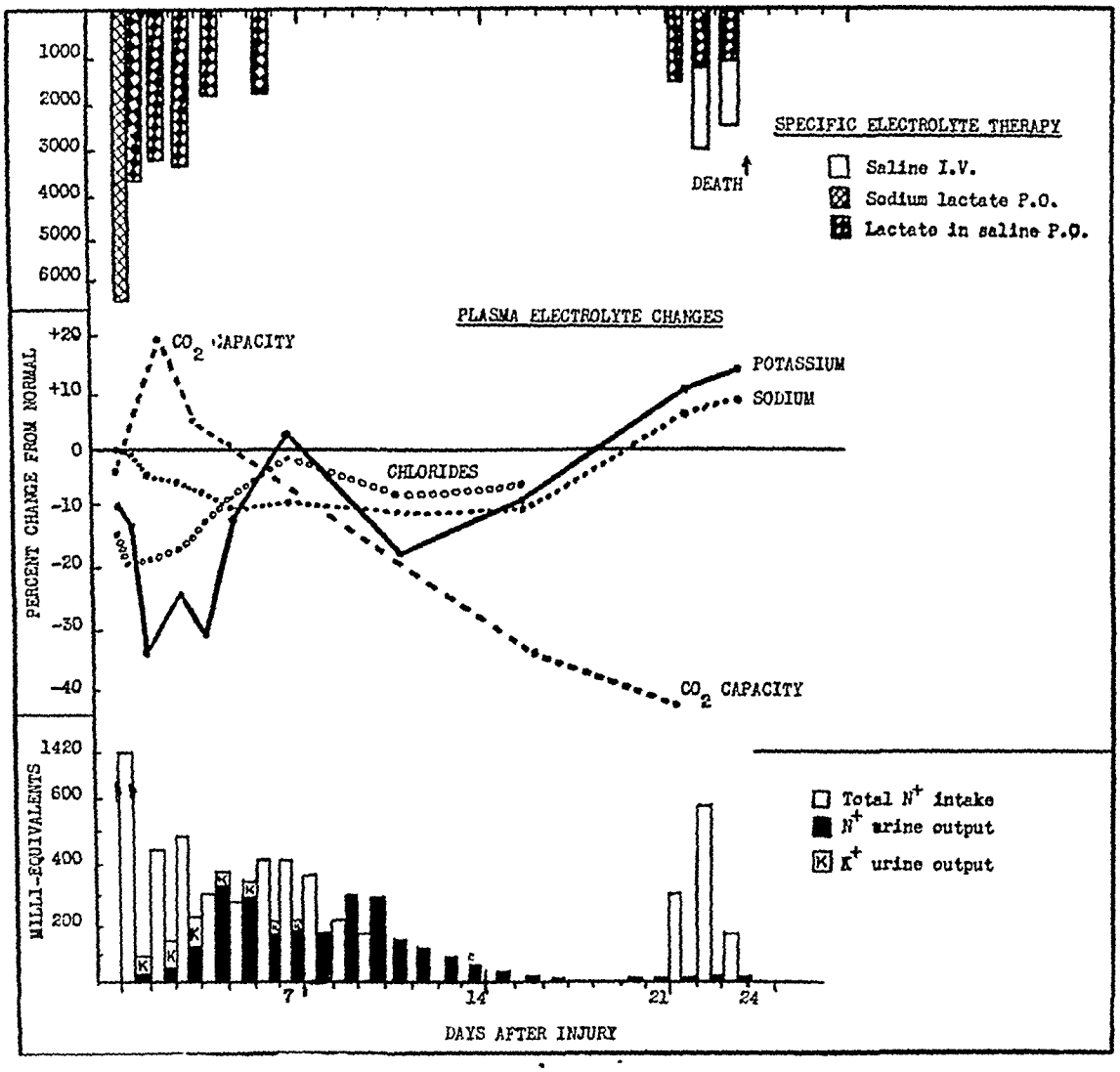



CHART VI-d.—Electrolyte intake, output and plasma changes in Case 6.

**Case 6.**—L. P., No. 729559 (Chart VI), a 29-year-old colored woman was admitted, December 13, 1943, approximately one hour after receiving a burn involving 44 per cent of her body surface. Her clothing had been ignited while she was fixing a stove. Treatment was managed by a combined group who agreed to give her oral electrolyte solutions *alone,* as advocated by Rosenthal and Fox. After a minimal cleansing the wounds were covered with an ointment gauze and pressure dressings. No intravenous therapy but nine liters of lactate and saline-lactate solution and two liters of other fluids were given orally during the first 24 hours. Urinary output during this time was 580 cc. and the patient vomited 4,300 cc. of fluid. Clinical signs of tetany were present on the following day but subsided after more saline and less lactate solution were given. Oral therapy alone was continued for two weeks with an average daily urinary output

of approximately two liters. Following the initial period of hemoconcentration there was a sharp fall in hematocrit and plasma protein levels to far below normal. Blood volume studies during this period were also subnormal by 20 to 40 per cent indicating that the actual anemia and hypoproteinemia was even greater than the deficits recorded on Chart V. Toward the end of the first week pulmonary complications developed which did not respond to sulfadiazine therapy. By the 14th day her condition appeared so critical it was felt that her only chance to survive lay in an effort to replace the protein and hemoglobin deficits by means of transfusions. In the next 11-day period 3,200 cc. of whole blood and 500 cc. of red cell suspension were transfused, with some improvement in her blood values. Additional lactate and saline were also given during the latter part of this period, but her general condition continued to grow worse and she expired on the 25th day of injury. In addition to the surface wounds the autopsy revealed pulmonary edema and congestion, bilateral hydrothorax, and partial atelectasis of both right and left lower lobes of the lungs.

COMMENT.—Oral lactate and saline solutions alone succeeded in sustaining this patient through the period of burn shock but left her with a *severe depletion of both hemoglobin and plasma proteins.* Some spontaneous recovery of the protein concentration was apparently accomplished by the mobilization of body reserves, but the anemia continued to get worse until transfusions were given. The difficulties of replacing such deficits once they are established have been mentioned by many other observers and it is generally agreed that it is much easier to prevent them or correct them by early transfusions. The forcing of electrolytes late in the course of this case, as in the previous case, was probably ill-advised in view of both the chemical and autopsy findings.

In contrast to the discouraging results obtained in the above two cases, the following four patients who suffered even more extensive burns are presented. They were given earlier and more intensive blood replacement with a successful outcome in each instance.

**Case 7.**—F. V. C., No. 757097 (Chart VII), a 27-year-old white chemist was admitted to the private pavilion, August 24, 1944, three days after suffering a flame burn involving 51 per cent of his body surface. While at work with some chemicals his clothing had been ignited and to extinguish the flames he had run across an open court to dive into a pond. The distribution of third-degree burns was almost identical to that in Case 6, but more extensive second-degree burns extended over most of his back. Shock therapy, given elsewhere, included the administration of 2,000 cc. of plasma during the first three days. After transfer to the Presbyterian Hospital blood studies showed he was still in a state of hemoconcentration, and an additional 1,600 cc. of plasma was transfused during the next three days. On the sixth day of injury his hematocrit was 25, indicating a severe deficit in red cell mass. During the next eight days he received a daily transfusion of whole blood or a total of 4,300 cc. for the eight-day period. After the sixth day of injury he took fluids and food by mouth extremely well, averaging over 200 grams of protein per day during the remainder of his hospital stay. Red cell concentration was kept within normal limits and his plasma proteins climbed steadily to normal and remained so. Healing progressed well and the third-degree areas were grafted on the 35th and 42nd days after injury, additional transfusions being given for operative support. Because of the shortage of donor sites "stamp" grafts were used except over the popliteal regions where full sheets of skin were placed. A good functional result was obtained, and the patient left the hospital walking three months and one week after injury.

COMMENT.—The conventional use of plasma in treating the shock phase of this case was successful but left him with a marked deficit in red cell mass. This was recognized early and enough blood to theoretically overcorrect the anemia was given. A quick return of appetite and progressive healing of the wounds followed.

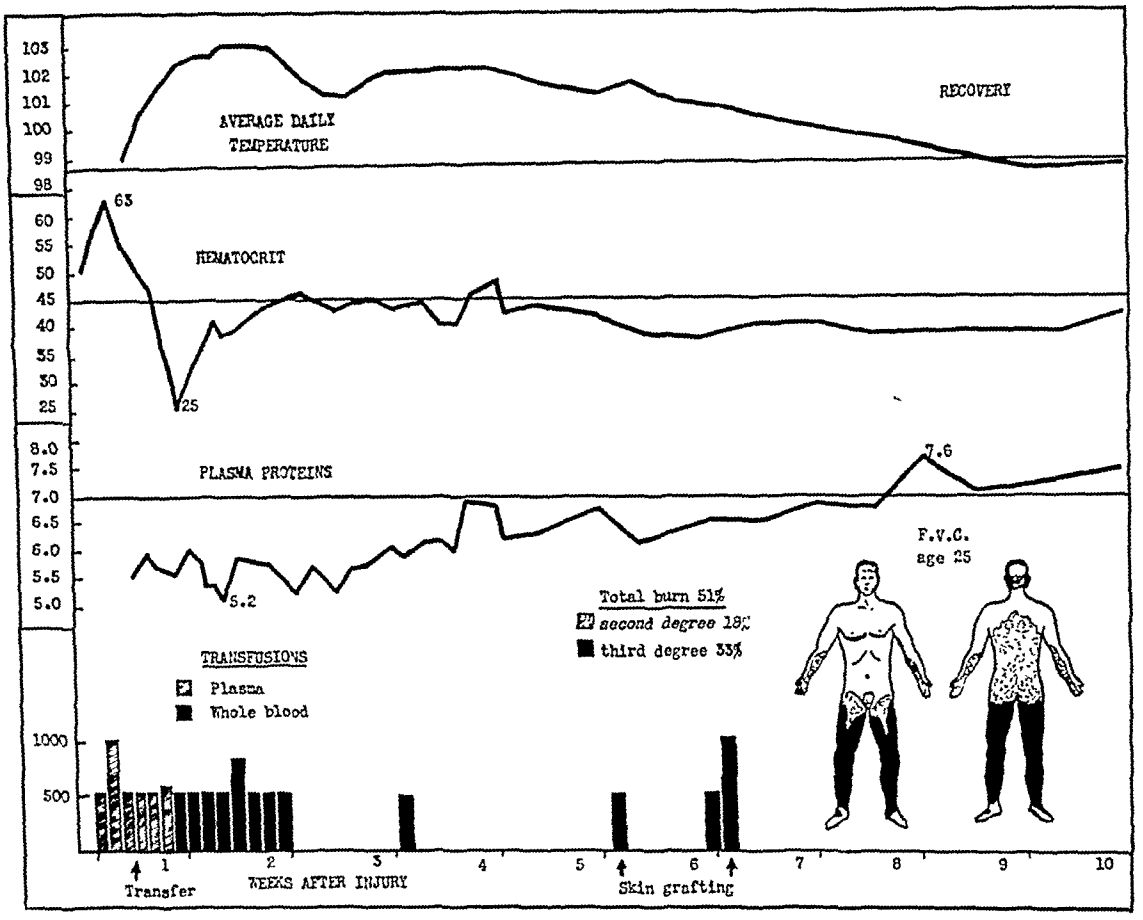



CHART VII.—Treatment and course of Case 7.

**Case 8.**—D. R., 644068 (Chart VIII-A), a 32-year-old elevator operator was burned on May 28, 1941, by an explosion of coal gas while lighting a furnace. He was admitted to the hospital 45 minutes later, with wounds involving 53 per cent of his body surface, largely second-degree in depth. Initial treatment included débridement of loose epidermis, application of a bland ointment dressing to the hands, forearms and face, and tannic acid-silver nitrate to the legs, buttocks and back. Replacement therapy consisted of 4,000 cc. of serum and 4,500 cc. of intravenous saline during the first 36 hours, with additional plasma and saline during the subsequent three days. By the sixth day a marked depletion in the hematocrit and plasma protein levels was apparent and whole blood transfusions were given daily for the next week and on alternate days for the following two weeks. The red cell and plasma protein deficits were soon corrected and the general course of the patient was satisfactory. Healing of the facial burns was complicated by an extensive infection of the left eye which necessitated evisceration on the 25th day. The tanned areas healed much slower than those treated with bland ointments and some skin grafting was necessary to aid healing in the scattered areas of full thickness loss. He left the hospital walking, four and one-half months after injury.

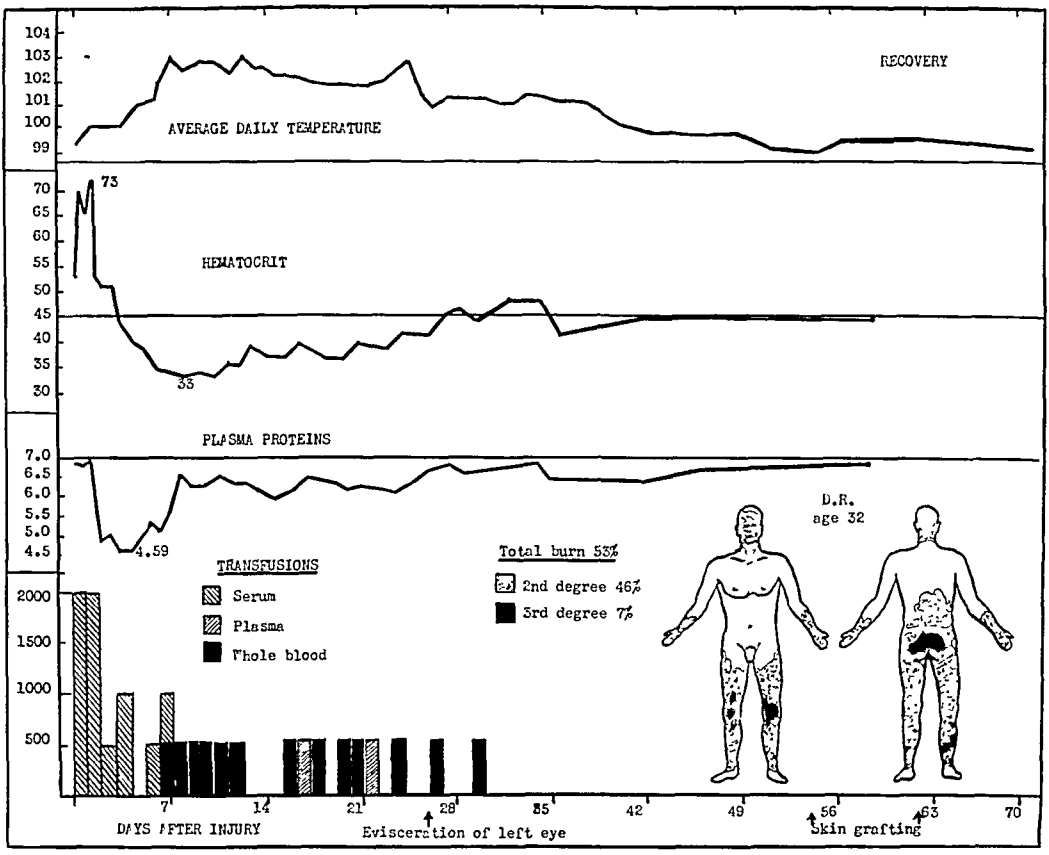



CHART VIII-a.—Treatment and course of Case 8.

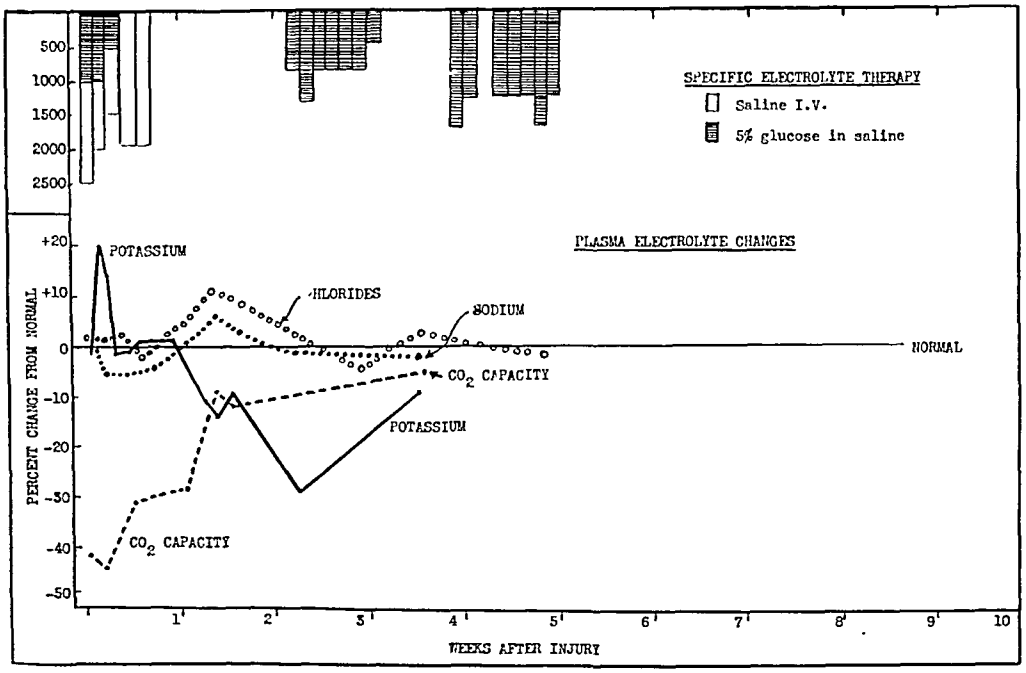



CHART VIII-b.—Electrolyte intake and plasma-changes in Case 8.

COMMENT.—The anemia of the post-shock phase was soon corrected in this case but might have been prevented had whole blood been given earlier. Also the acidosis of burn shock was slow in being corrected (Chart VIII-b) as compared with more recently treated cases given lactate solution (Chart XI). Local treatment with escharotics has since been abandoned by us because of the superior results obtained with pressure dressings and bland ointments.

**Case 9.**—J. N., No. 499757 (Chart IX), a nine-year-old colored girl who sustained a burn of 50 per cent of her body surface, January 24, 1944, when her clothing was ignited while she was lighting a candle at home. Early treatment, given elsewhere, con-

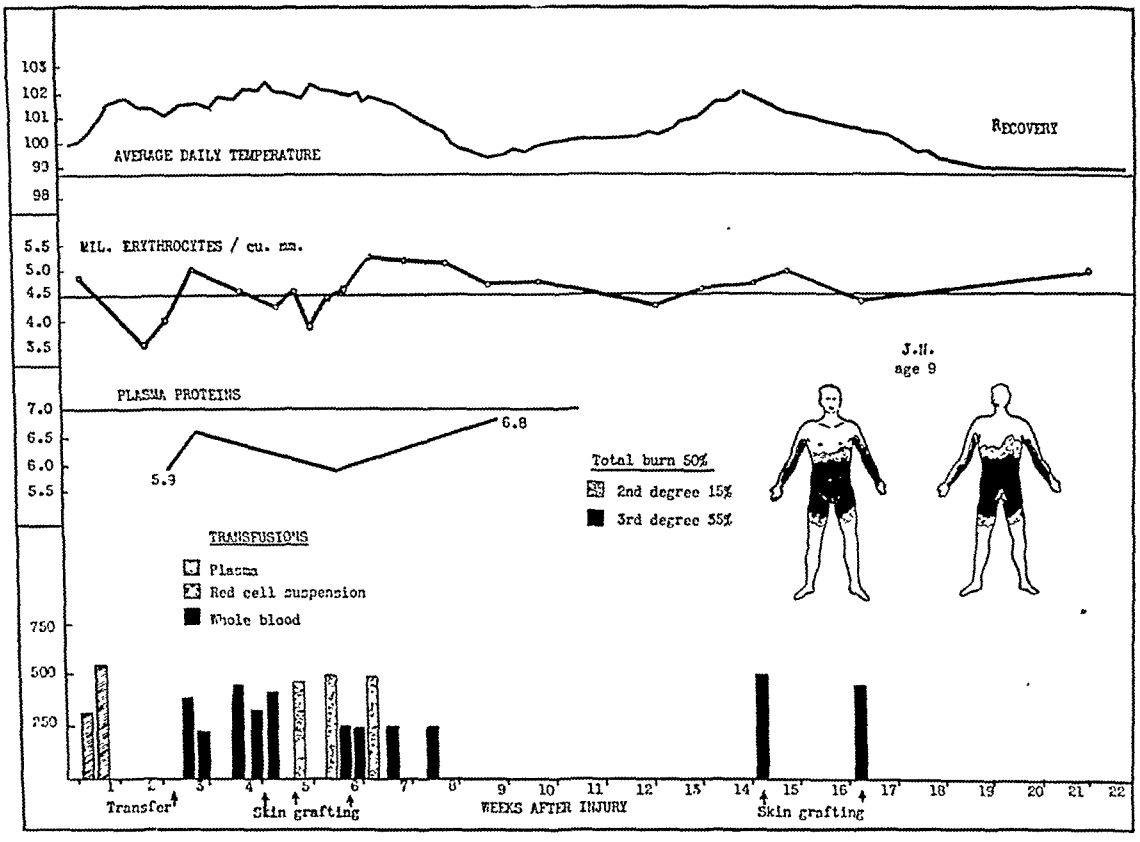



CHART IX.—Treatment and course of Case 9.

sisted of plasma and saline intravenously. The wounds were dressed with a variety of local applications. On February 9, 1944, 16 days after injury, she was transferred to our Plastic Surgery Service. Because of the demoralized state of the patient general anesthesia was used during dressings which were done at intervals of three to four days. A moderately severe anemia and hypoproteinemia were present upon admission and supportive therapy included frequent transfusions of whole blood and red cell suspensions totaling 4,550 cc. during the first month under our care, an amount equivalent to two and one-half times the normal circulating blood volume of the patient. Erythrocyte counts were maintained at a high normal during her most critical period. Within two weeks after transfer the slough had separated from the wounds and clean granulating surfaces were present (Fig. 6). Due to the magnitude of her wounds it was felt that autogenous skin grafting at this time might be too much for her to withstand. Accordingly, the patient's father was selected as a skin donor and eight dermatome sheets of skin (250 square inches) taken from him and used to cover the full-thickness

burn of her trunk and thighs. There was an immediate improvement in her appetite, morale and general appearance, anesthesia was no longer needed for dressings, and in the succeeding two weeks it was possible to apply autogenous grafts to both arms. With virtually all third-degree areas covered, the patient became nearly afebrile and was up and around the ward in a wheel chair. The secondary rise in her temperature noted between the 12th and 14th weeks (Chart IX) corresponded to the period of lysis of the homografts. By the time they had completely separated her arms and all second-degree wounds were fully healed and the total area remaining to be grafted was approximately half the size of her original wounds. She was in excellent condition to withstand the regrafting, which was done in two stages with the "stamp" graft technic, additional transfusions of whole blood being given for operative support. Fortunately, the patient did not develop keloids and a good functional result was obtained. She left the hospital walking, four and one-half months after admission.

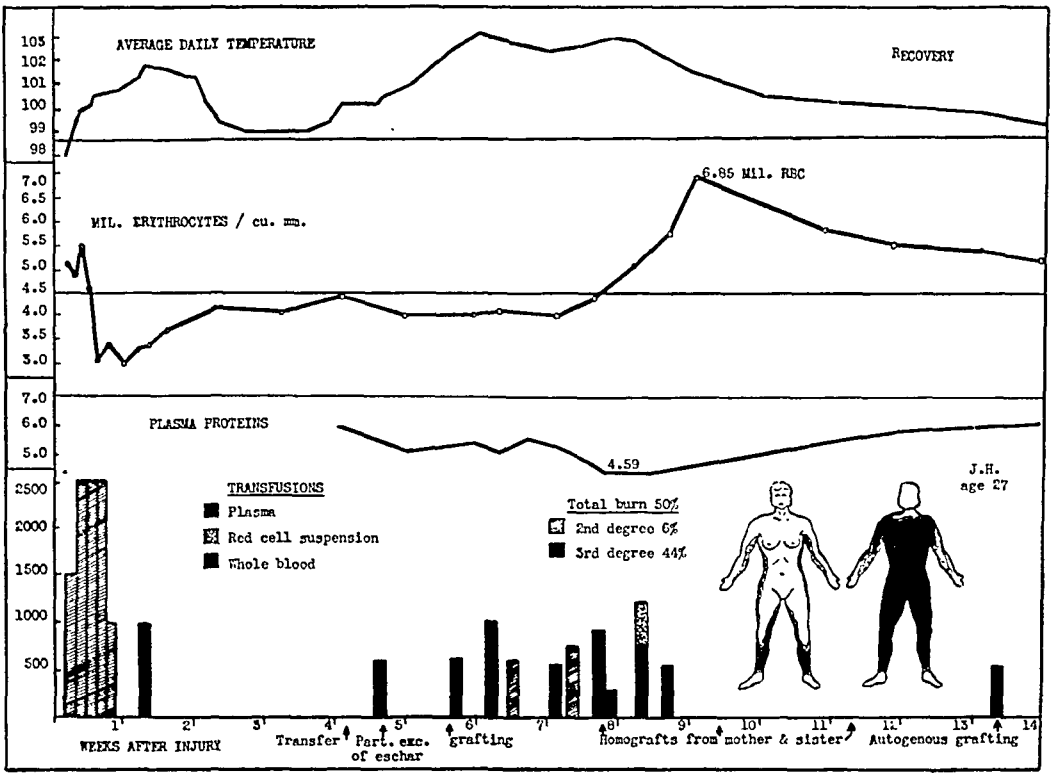



CHART X.—Treatment and course of Case 10.

COMMENT.—The liberal use of whole blood and red cell suspensions in this case was successful in maintaining both hemoglobin and plasma protein needs. Approximately one-half of her wounds were temporarily healed with homografts during the period when autogenous grafting and spontaneous healing were being accomplished in the remaining areas. Under this plan of treatment metabolic equilibrium was maintained through an extremely critical period.

**Case 10.**—J. H., No. 737446 (Chart X), a 27-year-old housewife who sustained a burn of 50 per cent of her body surface, January 22, 1944, when her dressing gown caught fire while she was tending her furnace. Initial therapy was carried out at a local hospital, where the wounds were treated with the triple-dye method. She re-

CHART XI.—The effect of sodium lactate therapy on plasma electrolytes in burns: The nonlactate treated group on the left shows slow elimination of excess potassium and inadequate correction of acidosis. The lactate-treated group on the right shows rapid decrease in potassium, overrorrection of acidosis and a tendency to hypochloremia.

ceived 10,000 cc. of plasma and 5,000 cc. of glucose intravenously during the first five days. Salt tablets totaling 10 Gm. daily and fluids, as tolerated, were given by mouth. *On the sixth day her hemoglobin* was 55 *per cent and* her erythrocyte count 3.0 million; 1,000 cc. of whole blood was then given and her erythrocyte count rose to 4.0 million. When transferred to the private service of Dr. Jerome P. Webster, one month after injury, she was in remarkably good condition. The triple-dye eschar was intact over the entire dorsal surface of her trunk and legs (Fig. 7), and there were no signs of infection beneath it. A portion of her arms which had been less deeply burned and had not received the eschar treatment were in the process of healing. Her blood studies at this time were at the lower limits of normal. On the fifth day after admission the eschar was surgically excised from the lower legs and part of the thighs. After a week on wet dressings, these areas were covered with autogenous "stamp" grafts which "took" satisfactorily. However, as other portions of the eschar became softened and undermined, the wound exudates increased in volume, her temperature rose, anorexia developed and wound-healing ceased. For a time it appeared her downward course could not be halted by the frequent transfusions of blood and plasma which were given. Still larger transfusions were used and when her outlook seemed hopeless she suddenly began to improve. Her erythrocyte count rose to 6.85 million, her temperature fell toward normal, appetite returned, wound exudates diminished, wound-healing was resumed and the nutritional edema which had developed in the hands, feet and labia disappeared. Her progress was slow but progressive. Homografts from the patient's mother and one sister (totaling 11 dermatome sheets of skin, Fig. 8) were used on the wounds until her general condition allowed further autogenous grafting which was carried out in three subsequent stages. A good functional result was obtained and the patient left the hospital walking, seven months after admission.

COMMENT.—Healing in this case was resumed only after an excess of red cells was supplied. It was of interest to note that the nutritional edema disappeared under this circumstance before there was a significant rise in plasma protein concentration.

### THE RATIONALE FOR GIVING LARGE VOLUMES OF WHOLE BLOOD DURING THE HEALING STAGE OF SEVERE BURNS

The presence of anemia is of course a recognized indication for blood transfusions during the healing stage of burns, but when hypoproteinemia is more severe than the red cell deficit it is generally felt that plasma, albumin, amigens or amino-acid infusions are indicated. Our experience suggests that whole blood rather than blood substitutes is more effective in maintaining nitrogen balance, and we feel that a moderate excess in red cell mass may be indicated during the healing stage of severe burns. Several reasons why this should be true are suggested:

(1) When the viscosity of the blood is reduced by the depletion of plasma proteins a moderate excess in red cell mass will increase the viscosity of the blood and thereby contribute to more nearly normal hemodynamics.

(2) As a source of protein whole blood contains almost twice the concentration of an equal volume of plasma since the hemoglobin content represents roughly two and one-half times as much protein as the plasma content of whole blood. When a unit of blood is given its plasma component is immediately available to augment the plasma proteins or body reserves; its red cell mass,

if in excess of normal, represents a rich store of protein, virtually the only method known by which a protein store of significant size can be immediately supplied to an individual. The fact that hemoglobin protein can be converted to other body uses has been experimentally demonstrated by the work of Whipple, and his associates.[17]

(3) An excess in red cell mass may have an immediate sparing action on body proteins by displacing plasma volume and thereby reducing the amount of plasma protein needed to maintain circulation. Protein so spared may be used in wound-healing. That such a mechanism occurs is suggested by our recent experimental work[11] in which large volumes of whole blood were given rapidly to dogs. Although the total blood volume could be increased immediately as much as 50 per cent by giving a transfusion equal to 100 per cent of the circulating blood volume of the animal, the total blood volume would fall off rapidly to about 15 per cent above normal and then gradually to normal. The immediate adjustment was accomplished by a reduction in plasma volume to accommodate the excess red cell mass and as the excess of erythrocytes was gradually eliminated the plasma volume increased to its original level. There appears to be little danger of precipitating pulmonary edema by the administration of whole blood alone, as noted in our experiments and as recorded in somewhat similar studies in dogs made by Beck and Holman.[19] When saline was given with the transfusions however, pulmonary edema was encountered.

(4) Patients in our series in whom the anemia was quickly corrected, or overcorrected, assimilated much more protein given by mouth than those in whom the anemia was not controlled.

(5) The patient in the process of forming a large granulating surface may have a physiologic increase in his total blood volume to aid in the process of healing just as the pregnant woman enlarges her circulating blood volume to meet the demands of the gravid uterus. Since patients with extensive burns usually lose considerable weight, the increase in blood volume may be relative rather than absolute. Further blood volume studies in extensive burns are needed to expand our knowledge of the physiology of wound healing.

## CONCLUSIONS

1. Replacement therapy in burn shock should be directed toward the restoration of all deficits in the circulating blood. These include red cells, plasma proteins, water and electrolytes. Whole blood transfusions fulfill these requirements more nearly than any other single agent.

2. Water and electrolytes can be administered to better advantage by mouth than by vein and will be absorbed in adequate amounts provided transfusions are also given. Sodium chloride solution in combination with lactate or bicarbonate is a more rational electrolyte mixture than sodium lactate solution alone in view of the tendency to alkalosis and hypochloremia which may result from vomiting and overalkalinization in burn shock.

3. The relative losses in plasma proteins and red cell mass may vary widely in different cases and are difficult to estimate during the period of hemoconcen-

tration unless blood volume determinations are available. In general, plasma losses will predominate in extensive second-degree burns while in third-degree burns the red cell mass lost from the circulation may equal or even exceed the losses in plasma volume.

4. If the anemia of the post-shock phase of a severe burn is not prevented by giving adequate amounts of whole blood in the shock period, it should be corrected as soon as it is recognized, for delay of even a few days may be disastrous.

5. During the healing phase of a severe burn whole blood should be administered in amounts adequate to theoretically overcorrect the anemia. If this is done the problem of maintaining nitrogen balance will be simplified.

6. In the presence of an anemia and hypoproteinemia uncontrolled electrolyte therapy by mouth or by vein is contraindicated since it will increase cellular edema and may lead to fatal pulmonary edema.

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# LESIONS OF THE MUSCULOTENDINOUS CUFF OF THE SHOULDER:

## III. OBSERVATIONS ON THE PATHOLOGY, COURSE AND TREATMENT OF CALCIFIC DEPOSITS

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THE FRACTURE SERVICE of the Presbyterian Hospital, in New York, has been fortunate in having had the opportunity to study a great many painful shoulders during the past 15 years. Included were almost 2,000 lesions in which the symptoms centered around a calcific deposit to produce the condition commonly diagnosed and treated as "calcified subdeltoid bursitis." Codman[2] pointed out many years ago that the offending deposit is neither calcified nor, when it requires therapy, is it in the bursa. Widespread acceptance of the fallacy that the lesion is calcified and within the bursa, as well as the multitude of diverse treatments advocated for cure of the symptoms it sometimes produces, indicates clearly that this common condition is still poorly understood and frequently mistreated.

Almost all of the many forms of therapy, both logical and empirical, have been given an adequate trial in the course of the study. As a base-line for evaluation of the results there has been available a large series of cases which had no treatment other than sedation and palliation of pain. The long term follow-up has been somewhat less than adequate in many instances. However, the conclusions to be expressed concerning the immediate effect of various therapies are based upon adequate and critical clinical observations on the part of a trained personnel and embrace a large series of cases.

These conclusions may be stated very briefly. All adequately followed cases eventually recovered from their painful symptoms. This was true regardless of the type, presence or absence of treatment. The only variants included the character, severity and duration of pain and the occasional presence of certain general or local complicating factors resulting from the presence of a painful focus in the shoulder region. Certain treatments produced sure and speedy relief of symptoms within a time-period constant enough to allow of prognostication. Most treatments were accompanied, or followed by, relief at variable and inconstant periods following the inception of therapy. Upon analysis, the latter group were found to have a recovery rate quite comparable to that of the control cases who had no therapy other than sedation. In short, most of the therapies in common usage, while usually producing temporary amelioration of pain, had no appreciable effect upon the speed or completeness of the eventual recovery.

Gross, microscopic and bacteriologic studies of the condition have been possible in about 200 cases which were subjected to operation. This series included

cases in all stages of the condition, from the most mild to the most severe in degree. Operative findings correlated with pre- and postoperative clinical observations and, analyzed in comparison to the behavior of similar unexplored cases, have thrown considerable light upon the true nature and course of the condition. As a result it is now considered possible to reconstruct with reasonable certainty what might be termed the life cycle of the lesion and, *ipso facto,* a logical rationale for therapy.

### ORIGIN

Codman maintained the lesion to be traumatic in origin with tendon degeneration and calcium deposition occurring as a secondary phenomenon. Meyer,[3] and others, hold degeneration to be the primary change, followed at times by secondary rupture of the degenerated fibers. There is some evidence to support the latter contention. Figure 1 shows degeneration of the tendon fibers of the supraspinatus, with minute diffuse deposition of calcium throughout the degenerated areas but no evidence of inflammation or rupture of the involved fibers. This section constitutes evidence that at least some degeneration and calcium deposition may occur without antecedent minute rupture of the tendon fibers. On the other hand, there is ample clinical evidence that trauma can activate painful symptoms around a previously quiescent or asymptomatic deposit. The onset of the clinical syndrome frequently follows within a few hours after a mild injury or over-use of the arm.

The earliest microscopic evidences of the lesion consist of hyaline degeneration in the collagen of the tendon fibers. The involved fibers soon become fibrillated and form what Codman called "straps" or loosened bands of fibers within the substance of the tendon. Motion of the part, aided by progression of the local degenerative change, further loosens these fibrillated strands, finally breaks them free from their attachments to the more normal surrounding tendon and curls them into rice-like bodies occupying a cavity within the substance of the tendon. Continued motion grinds these rice-like particles into a finely pulverized wen-like substance composed of necrotic tendon débris. Such a collection may or may not be characterized by the deposition of calcium salts in sufficient concentration so that an opaque shadow is produced on the roentgenogram. The shoulder from which the microscopic section illustrated in Figure 1 was taken showed no radiopaque shadow, and other nonopaque collections of tendon débris accidently encountered in the course of a tendon operation performed for some other condition, when subjected to chemical analyses, have shown a high concentration of calcium. It has been apparent, however, that almost all deposits productive of pain in the shoulder contain a sufficient concentration of calcium salts so that their presence and anatomic location become demonstrable by adequate roentgenologic studies of the part.

### MECHANISM OF PAIN PRODUCTION

The predominant symptom associated with irritation by a calcific deposit

is pain in the shoulder region. It results from tissue tension at the site of an inflammatory reaction around the offending deposit. This inflammation is centered in and fairly well-restricted to the vascular peritendinous tissues rather than in the tendon tissues. The peritendinous structures associated with



FIG 1.—High power view of section taken from supraspinatus tendon. X-ray showed no opaque shadow. Degeneration, loss of nuclei and deposition of cacium within the tendon fibers and no evidence of rupture or inflammatory change is present.

most round tendons consist of epitenon, or a tubular synovial sheath. That associated with the short rotator tendons of the shoulder consists of the synovial floor of the subdeltoid bursa. Therefore, while inflammation resulting from irritation by a calcific deposit may produce the clinical syndrome of tenosynovitis in tendons having tubular sheaths, it produces the syndrome of subdeltoid bursitis in the shoulder. The microscopic characteristics of the inflammatory reaction are not extraordinary except for the constant presence of giant cells, typical of tissue reaction to irritation by a foreign body. Bacteriologic investigations have failed to demonstrate the presence of aerobic, anaerobic or virus organisms. The deposit, composed of necrotic tendon débris, is a foreign protein and it, therefore, has seemed logical to

conclude that the inflammation is in fact a foreign body reaction to tissue irritation by its contents. This postulation provides the only logical explanation for certain peculiarities in the behavior of the lesion that, prior to increased knowledge resulting from operative examinations, were somewhat puzzling.

### QUIESCENT OR ASYMPTOMATIC DEPOSITS

Calcific deposits in the shoulder are peculiar in that they are encountered roentgenologically in the complete absence of any past or present symptoms, almost as frequently as they are found accompanied by symptoms. Boardman Bosworth[1] found quiescent deposits in 165 of 6,061 normal shoulders. Two facts explain the quiescence of such lesions. The first is that the deposit originally forms in the tendon where it is enclosed within almost avascular tissues. The second is that the *sine qua non* for mobilization of an inflammatory reaction is adequate minute local circulation. Consequently, in the early stages while the deposit is surrounded by relatively avascular tendon tissue a minimal inflammatory reaction, if any, is possible.

Many asymptomatic lesions, discovered by roentgenograms taken for some other condition, have returned at a later date with pain due to irritation by the previously quiescent deposit. Probably most quiescent lesions eventually develop symptoms in some degree since the symptoms are nothing more than a subjective manifestation of nature's attempt to eradicate the lesion. It has been apparent that so long as the deposit remains buried in tendon it tends to remain quiescent, but that sooner, or later, it gradually or suddenly penetrates the overlying tendon fibers to come into contact with the floor of the subdeltoid bursa, following which an inflammatory reaction immediately is mobilized with ensuing symptoms.

### VARIATION OF SYMPTOMS IN LESIONS APPEARING IDENTICAL BY ROENTGENOLOGY

Operative findings have demonstrated that the degree of inflammation varies in accordance with the quantity of irritant material in contact with the bursal floor. This explains another previously puzzling peculiarity of the lesion, *i.e.*, the great variation in severity of pain accompanying deposits that seem of identical size by roentgenogram. There is no relation between the size of the deposit and the severity of the symptoms to be expected. The explanation rests in the fact that symptoms vary as the amount of material actively irritating the bursal floor rather than the total quantity of the material as judged by the size of the deposit.

It has been found that mild or intermittent chronic symptoms are to be expected when a few particles of the deposit penetrate the tendon and come into contact with well-vascularized peritendinous tissue. Such symptoms may subside if the amount of irritant is small enough to be absorbed and eliminated by phagocytosis, only to recur upon penetration of the tendon by additional material from the buried deposit.

Acutely painful lesions are found to have a major portion of the deposit in

contact with the bursal floor. Release of a large portion of the material from the depths of the tendon cavity may result from degeneration and final spontaneous rupture of the tendon fibers overlying the deposit. Such is the mechanism for production of acute attacks that commence without known cause. The softened overlying tendon fibers also may be ruptured by a minor wrench or overuse of the arm, as attested by the high incidence of acute attacks that come on a few hours after some minor injury or strain. Minute traumatic factors of this type may be overlooked but are of considerable importance for the establishment of compensability when the syndrome occurs in connection with occupation.

There is little difference between any two acute incidents from a clinical viewpoint. It has been demonstrated beyond doubt, however, that the location of the deposit is of some importance in determining the character of the symptoms during the chronic stages of the condition. Prior to the increased knowledge, made available by operative investigations, it was difficult to understand why two apparently identical lesions should produce, on the one hand, a constant ache, and, on the other, nothing more than acute catches of pain in the shoulder on certain motions. Deposits in the subscapularis tendon often remain quiescent until, or unless, an acute attack supervenes. Those in the supraspinatus or anterior portion of the infraspinatus tend to produce a constant ache aggravated by motion. Those in the posterior portion of the infraspinatus, or the teres minor, are characterized by sharp catches of pain on certain motions such as putting the arm into a coat sleeve and are apt to remain asymptomatic at other times. Exploration under local anesthesia has demonstrated that pain constantly is accentuated by any increased tension in the tendon containing the deposit and markedly aggravated by compression of the inflamed tissues around the deposit against the acromion or the anterior edge of the coraco-acromial ligament. It is, therefore, only logical that a deposit in the supraspinatus portion of the cuff where it is under constant tension by gravity and crushed against the acromion on almost every glenohumeral motion should produce more severe and constant chronic symptoms than one in the anterior or posterior portion of the cuff where gravity plays a relatively unimportant rôle and where impingement against the acromion is possible only in certain extremes of position.

### VARIATIONS IN LOCAL PATHOLOGY

The consistency of the material within the deposit and the tension under which it is enclosed within the tendon cavity constitutes two constant differences between the acute and the chronic lesion. The deposit productive of chronic symptoms invariably is dry, cheesy or wen-like, and infiltrated through tendon tissue within a relatively poorly circumscribed cavity under little or no tension. The deposit productive of acute pain is always wet, greasy, and the consistency of tooth paste or heavy cream. In addition, the acute lesion always is under distinct tension within a rather well-defined cavity from which the material is apt to spurt upon incision. This change in the consistency and ten-

sion of the lesion results from infiltration and dilution of the dry chronic or quiescent deposit by inflammatory exudate as irritation progresses. Both the relative consistency and tension of the lesion may be determined by interpretation of the roentgenograms. The chronic lesion is roentgenologically manifested by a rather dense shadow with an ill-defined or irregular periphery, whereas the acutely inflamed deposit is represented by a well-defined globular and frequently flocculent shadow of relatively less opacity. Evaluation and determination of both the consistency and tension of the deposit as well as the exact anatomic location is of some therapeutic import as will be illustrated by the results of certain needling procedures.

### NORMAL COURSE OF THE LESION IF UNTREATED

Chronic stages of the condition may persist over a lengthly interval. The study includes patients with a history of more or less constant mild pain for as long as 15 years. A great many patients, first seen because of mild and chronic symptoms, subsequently returned for treatment of a superimposed acute attack. A considerable percentage of the patients suffering from an acute episode gave a history of antecedent minor symptoms. These facts, in conjunction with the rarity of the lesion in the anatomy laboratory where unselected cadavers exceed 66 years of age, indicate that most, if not all, deposits are eliminated by some spontaneous mechanism prior to the sixth decade and tend to confirm the conviction arrived at from operative investigations that this mechanism consists of the inflammatory phenomena under discussion.

It seems probable that intermittent attacks of mild or moderate pain represent a mechanism for gradual depletion and eventual elimination of the deposit by repeated inflammatory responses of minor degree, each of which phagocytizes a small amount of the irritant material. It has been demonstrated, conclusively, that the acute episode also represents a spontaneous mechanism for eradication of the lesion. In direct proportion to increasing severity of the symptoms there occurs an increased degree of inflammation around the deposit. The enclosed material becomes diluted by exudate and the lesion presents as a tense, furuncle-like swelling in the bursal floor. The subsequent train of events somewhat simulates that of a furuncle. Tension increases until rupture occurs, following which the contents of the deposit are discharged into the synovia-lined cavity of the bursa and absorbed. As soon as rupture takes place the intense throbbing pain characteristic of the acute stage commences to subside. Within a few days not only do the symptoms disappear, but so also does the roentgenologic evidence of the deposit. Operative findings have shown that the tendon cavity fills-in by granulation with eventual fibrous tissue replacement of the residual defect.

The self-limiting character of the condition makes the prognosis for eventual recovery from any one attack reasonably certain. Multiple deposits in the same shoulder seldom produce symptoms simultaneously and such a condition is the usual cause of recurrent acute episodes. The unknown factors in

the prognosis of a single lesion include only the severity and duration of the symptoms to be expected. Consequently, the therapeutic problem concerns not the question of recovery as much as the time of recovery and the control of pain during symptomatic stages of the condition.

## THERAPY

No therapy designed to combat a calcific lesion is warranted except in the presence of symptoms which on clinical and roentgenologic examination are with reasonable certainty the result of irritation by the deposit. Pain in the upper extremity may emanate from many sources and the incidental presence of a calcific deposit in the shoulder region may result in a waste of valuable time and effort and allow the true etiologic agent to progress needlessly if therapy is administered on the basis of roentgenologic evidence alone. Several malignant lesions of the upper humerus, a number of herniated cervical disks, and a considerable number of coronary lesions have been encountered which gave a history of protracted and useless treatment designed to combat the effects of harmless, incidental calcific deposits in the shoulder prior to recognition of the true cause of pain.

Following determination that the deposit is the cause of pain therapy may be indicated for one of two reasons. It may be required as a palliative measure for the reduction and control of pain during the symptomatic period accompanying the spontaneous eradication of the irritating focus. It may be required as a curative agent by reason of symptoms, the duration or severity of which warrant more than palliative treatment from the patient's point of view. No therapy is warranted by the presence of a deposit, *per se,* unless, or until, the lesion produces pain. Analysis of the results following the many forms of therapy that have been evaluated during the course of this study leads to the conclusion that the only curative therapies available are those designed to simulate nature's method of cure, *i.e.,* eradication of the offending deposit. All others are chiefly palliative in effect and their professed curative powers, when examined in the light of the known self-limiting nature of the local pathology and compared to adequate controls, have been disproved or found to be purely empirical in nature. Radiation therapy, the exact mechanism and effect of which is still incompletely understood, appears to occupy an intermediate therapeutic status in the light of present knowledge. It has proved of frequent but inconstant value in providing speedy relief of pain in the acute cases. In the chronic cases it has proved of negligible value and is worthy of mention only for emphasis of its potential dangers. It is in the chronic case that the temptation to give just a little more therapy is most prevalent and catastrophic burns may result. Only two curative measures have been proved by an adequate series of recoveries which took place within a constant time-period.

### 1. NEEDLING PROCEDURES

Various types of needling procedures have been practised. The only one productive of constant, speedy, and permanent relief of symptoms was that

which evolved from an understanding of the local pathology as described above and which undertook to insert the needle into the cavity containing the irritant material and deflate the tension within the cavity by puncture and aspiration of its contents. Even this procedure proved of uncertain value in the treatment of chronic lesions. The dry material characteristic of the chronic lesion can be aspirated only with difficulty and after surgical dilution by injecting into it a sufficient quantity of saline so that the resultant mixture becomes semifluid enough to go through a needle. This can be done only in a few selected cases and the over-all results following attempts to aspirate a considerable number of chronic lesions was disappointing enough so that the practice has been discontinued. Puncture alone is sufficient to produce immediate reduction of pain in the acute case and complete subsidence of pain within the next few days. Aspiration of some of the contents of the acutely inflamed deposit is considered advisable, not from a curative standpoint, but because recovery of the material from the deposit constitutes evidence that the aim of the procedure, puncture of the tense cavity, has been accomplished. Such a procedure guarantees the patient suffering from an acutely inflamed deposit immediate relief of the intense throbbing pain and progressive subsidence of any residual ache so that complete and permanent recovery occurs within a few days. Other needling procedures such as regional infiltration with novacaine, multiple perforations of the bursa, and irrigation of the bursal cavity have been followed by frequent but inconstant relief of pain in acute cases.

The general trend of clinical evidence indicates that any agent or procedure which temporarily eliminates pain and allows motion of the arm may indirectly result in rupture of the tense acutely inflamed deposit if it is in a location where it becomes pinched on motion of the shoulder. For this reason many therapeutic procedures may be followed by a considerable percentage of cures even though they are employed as a routine rather than as a method for the accomplishment of a specific purpose, arrived at through logical rationale.

### 2. OPERATIVE REMOVAL OF THE DEPOSIT

Almost 200 cases have been explored and had the deposit or deposits removed. This method of treatment produces the most certain and permanent results. It has been necessary in less than ten per cent of all cases, and the great majority of operated cases were done as a procedure of choice on the part of the patient. Only twice has operative removal been considered imperative. Both cases were in acute pain which seriously jeopardized the status of a coincident condition; one, a pneumonia and the other, a precarious pregnancy. Both deposits, although acutely inflamed, were not amenable to aspiration and operative removal was carried out under local anesthesia. The incidence of recurrent attacks of acute pain due to multiple deposits has been high enough to warrant consideration of operation as an advisable procedure when more than one deposit is found in an acutely inflamed shoulder. Otherwise the most tenable indication for operation is present in the chronic

condition productive of symptoms sufficiently protracted or severe to warrant it from the patient's point of view. Preoperative localization of the lesion and adequate placement of the surgical approach makes the procedure a minor one. An incision more than three centimeters in length is rarely necessary. No postoperative restriction of motion or use is necessary or wise and the total hospitalization required seldom exceeds three days.

### CHOICE OF TREATMENT

The study has resulted in the evolution of a simple clinical philosophy based upon an increased understanding of the lesion. The immediate problem usually demands a decision between curative and purely palliative therapy. Seldom is anyone but the patient qualified to make such a decision. After a full explanation of all aspects of the situation he is asked to decide whether he can carry on comfortably with appropriate help in controlling the symptoms and with a reasonably certain expectation of eventual spontaneous recovery, or whether the symptoms warrant more radical curative therapy in an effort to eliminate them quickly and permanently.

The chronic condition warranting curative therapy deserves operative removal of the deposit as the only certain and speedy method of obtaining permanent relief.

The chronic condition warranting nothing more than palliation may be treated by any combination of sedative measures that are convenient and that result in reduction of pain. Therapy that fails to do this is not worth while. Simple home measures including heat, aspirin and a program designed to prevent disuse and stiffness of the arm have been found to be as efficient as all types of formal therapy.

The acute condition warrants curative therapy. The treatment of choice is puncture of the tense deposit and aspiration of its contents by needle under local anesthesia. Palliation usually is necessary during the next few days. Multiple deposits in the acutely inflamed shoulder and certain other selected acute cases warrant operative intervention.

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# MASSIVE PANCREATIC HEMORRHAGE*

CASE REPORT

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CASES of acute hemorrhagic pancreatitis in which recovery has occurred have been reported in increasing numbers in recent years. Many of the recoveries have been in patients upon whom no operation was performed. Accordingly, the more certain recognition of the lesion by means of blood amylase studies has made many surgeons feel that operation should not be undertaken when a definite diagnosis can be made with any degree of confidence. However, in the minds of most physicians there is still present a belief that most of the severe cases will die regardless of the form of treatment. Because of this impression it seems worth while to record a case in which, at operation, the pancreas seemed to be replaced by a massive hematoma and yet the patient recovered and has remained well for eight years. No report of a similar case has been found since the paper of F. W. Draper,[1] a medical examiner in Boston, was published in 1886.

**Case Report.**—The patient, a white male, age 55, was admitted to the Episcopal Hospital, in Philadelphia, at 11 P.M., December 5, 1937, complaining of severe pain in the upper part of his abdomen. At 10 A.M. that morning he had noticed a heavy feeling in his epigastrium and a short while later vomited several times. This was followed by the appearance of severe pain in the upper abdomen which in two hours failed to be affected by the administration of morphine. He grew progressively worse in spite of ingesting a large number of pills given for the relief of his pain.

For the past two years he had been working as a machinist. For several months he had been treated by his doctor for a vague type of indigestion. He had never smoked and drank only sparingly. Two years previously he had injured his pelvis in an automobile accident but had no persisting disability.

*Physical Examination.*—Upon his admission to the hospital, he was seen to be a frail, sick-looking man, apparently suffering from severe abdominal pain. There was no apparent jaundice or cyanosis, and he showed no evidence of dehydration. Temperature 96.4°F ; pulse 80, respirations 20. The peripheral blood vessels showed thickening of their walls. The chest was normal and the heart sounds were regular and of fair quality, without murmurs. Blood pressure 122/80. The area of liver dullness started at the sixth rib in front and was diminished in the axilla. The abdominal wall was retracted and showed no appreciable movement on respiration. There was diffuse tenderness and muscle spasm but the most marked tenderness was in the left upper quadrant and in the left flank. Peristalsis was not audible. Rectal examination revealed fullness high up anteriorly and tenderness in the same area. White blood cell count 16,000, with 94 per cent polymorphonuclears, of which half were unsegmented forms. The urine showed traces of albumen and of acetone, and hyaline casts, but no sugar. A diagnosis of acute hemorrhagic pancreatitis was thought to be more suitable than one of acute perforation of a gastric or duodenal ulcer and operation decided upon. He was given morphine sulphate

* This case was originally presented at the combined meeting of the New York Surgical Society and the Philadelphia Academy of Surgery, in Philadelphia, February 14, 1940.

and scopolamine and an intravenous infusion of 5 per cent glucose in normal salt solution, 250 cc., before going to the operating room.

*Operation.*—Spinal anesthesia with pontocaine (0.11 Gm. in 3 cc. of 10 per cent glucose solution) preceded by the subcutaneous injection of ephedrine sulphate (.050 Gm.) 20 minutes before. A right subcostal incision was made and practically no bleeding was encountered even when the rectus muscle was cut across. The blood pressure was then found to be 44, and epinephrine was injected subcutaneously and an intravenous infusion of 10 per cent glucose in normal salt solution started. There was immediate improvement, and the operation was continued without any further difficulty. On incising the peritoneum there was an escape of dark blood. The peritoneal surfaces appeared normal, there was no fat necrosis and no exudate. In the base of the transverse mesocolon dark blood could be seen, and in the region of the pancreas could be felt, a firm mass about eight times the normal size of that organ. On incising the peritoneum over the head of the pancreas the mass was found to be a large hematoma but no active bleeding could be demonstrated. The liver was somewhat pale but the spleen and other organs appeared to be normal. Although the gallbladder showed no evidence of disease and was not distended a cholecystostomy was performed to allow for the fullest decompression of the biliary tract. The gallbladder bile was black and liquid. A catheter, with fenestrations, was inserted and held in place by two purse-string sutures. Omentum was wrapped around the tube which was brought out through the wound. The abdominal wall was closed with interrupted through-and-through sutures of silkworm gut. At the end of the operation the patient's condition was fair.

The next morning his condition was quite good, and from then on he made a slow but progressive recovery with a marked temporary disturbance of his sugar metabolism and with attacks of pain in the region of his pancreas.

*Subsequent Course.*—During the first few days he had suction drainage of his stomach maintained and fluids were given intravenously. On the first day after operation his blood sugar was found to be 322 mg. per cent and he had sugar in his urine. His urinary amylase was also found to be slightly elevated this first day. After that one unit of insulin was given with every 2.5 Gm. of glucose given intravenously and a diabetic regimen inaugurated. By the fifth day the blood sugar had fallen to 148 mg. per cent. From this date onward the blood sugar fell and did not rise again except on one occasion. His diet was gradually increased and the insulin regulated. By the time of his discharge from the hospital, February 20, 1938, he was tolerating a diet of 2,500 calories without insulin and without spilling any sugar into his urine. Two glucose tolerance tests were done, with evidence of considerable improvement in the one of February 15.

His wound healed by primary intention except for the drainage tract. Bile drained in small amounts and varied in quality. When it was thin and watery he had no discomfort. When it became dark and thick, as it did at times, he had a dull pain in the region of the pancreas. Several small flat calculi were passed from the drainage tract on the 27th day after operation, but within 18 days after this all drainage had stopped.

He had several attacks of pain in the region of the pancreas, associated with sweating and with a drop in blood pressure. The worst one occurred on Christmas morning, 20 days after operation, and was so severe that it was thought he might die. However, following the administration of epinephrine, and of glucose intravenously he promptly recovered, but for a week thereafter ran fever and for another week he had a variously-sized mass in the region of the pancreas, which was quite tender. This mass was thought to be due to a necrosis of the pancreas but its disappearance within two weeks without the subsequent discharge of any necrotic material from his drainage tract seemed to rule out this possibility.

His blood pressure, except during the attacks of supposed hypoglycemic shock, seemed to vary inversely with his asthenia. During the first six days when he seemed prostrated the pressure varied between 130/70 and 140/78, with only two recordings

lower than this, and the pressure was determined every four hours. As he improved and felt stronger the blood pressure fell to a lower level and ranged between 90/62 and 120/70, with the average about 100/70.

Following discharge from the hospital he was examined at frequent intervals for the next two years. He regained his strength slowly, but had no other symptoms. His fasting blood sugar was consistently normal and he showed no sugar in his urine, although on a liberal diet without candy or similar sweets. In January and February,

TABLE I

SUMMARY OF LABORATORY STUDIES*

Bacteriologic:
Peritoneal fluid at time of operation. Culture—no growth.
Bile obtained from gallbladder at operation. Culture—Bacilli (identification of the Bacilli was not made).

Chemical Studies:
Bile from gallbladder at operation—bile salts and chloride normal.
Urinary amylase 1st day after operation—slightly increased. 4 weeks later—normal.
Two years after operation:
Blood amylase (colorimetric test) Feb. 1940—Normal
Blood lipase Feb. 1940—Normal

Blood Wassermann and Kahn: Dec. 6, 1937—Negative.

| Blood Sugar— | | | |
|---|---|---|---|
| Dec. | 6, 1937 | 322 mg.% | |
| | 7, | 250 | |
| | 8, | 218 | $CO_2$ 57.9 vol. % |
| | 10, | 250 | |
| | 11, | 148 | |
| | 12, | 127 | $CO_2$ 66.3 |
| | 13, | 148 | 48 |
| | 14, | 120 | |
| | 15, | 107 | |
| | 16, | 118 | |

After January 5, 1938 it never was above 110.

*Glucose Tolerance Tests*
*(100 Gm. glucose given)*

| | Blood Sugar Readings | | | | | Urinary Sugar Readings | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Fasting | After 30 Min. | After 60 Min. | After 2 Hrs. | After 3 Hrs. | Fasting | 30 Min. | 60 Min. | 2 Hrs. | 3 Hrs. |
| Feb. 2, 1938 | 86 mg. % | 190 | 262 | 252 | 208 | Neg. | Neg. | Neg. | 1% | 1% |
| Feb. 15, 1938 | 93 | 123 | 212 | | | Neg. | Neg. | Neg. | | |
| Mar. 29, 1938 | 101 | 147 | 308 | 344 | | Neg. | No spec. | Neg. | No spec. | |
| Jan. 30, 1940 | 89 | 117 | 254 | 172 | 226 | Neg. | Neg. | | | |

*Liver Function Tests*
*February 1940*

Hippuric acid 2.6 Gm. Bromsulphalein—18 min. 3% retention, 30, 60 min.—none.
Cholecystogram—Gallbladder filled well but only half emptied contents after fatty meal.

* The chemical studies on the bile were done by Dr. Cecelia Riegel, and the amylase and lipase determinations by Dr. Daniel Dozzi, in the Laboratory of Research Surgery of the University of Pennsylvania.

1940, studies of his liver function by means of the hippuric acid excretion test and bromsulphalein excretion showed no evidence of impairment. Blood amalyse and blood lipase studies were also normal. A cholecystogram, in February, 1940, showed normal filling of the gallbladder, but it only half emptied after the fatty meal. He has continued to work and lead a normal life, without symptoms, but has had to follow a diet to keep his blood sugar within normal limits. During 1945 his blood sugar varied between 107 mg. per cent in April to 176 in December (Table I).

COMMENT.—This then was a case in which a considerable part of the pancreas was involved in an hemorrhagic process which did not produce any apparent fat necrosis or peritonitis. No source for the hemorrhage could be found, and the diffuse involvement of the organ seems strong evidence against a vascular accident. The severe diabetes which was present immediately following the operation would indicate a considerable suppression of the pancreatic islet activity. No material which resembled necrotic tissue ever escaped from the drainage tract. Furthermore, the diabetes gradually became less and less severe so that on his discharge from the hospital the only evidence of it was seen in the glucose tolerance test. This demonstrates the reversibility of the process but its true nature is not apparent.

Whether the operative intervention was of value, or not, cannot be definitely stated. Although the diagnosis of acute hemorrhagic pancreatitis was considered before operation there was also considerable support for the diagnosis of acute perforation of a duodenal or gastric ulcer. No blood amylase study was made, but even had it been done and had shown evidence of pancreatic damage it would have been felt that an exploratory operation was still necessary.

The value of cholecystostomy is also problematic. There was no evidence of biliary tract disease at the time of the operation, or from a study of the bile removed from the gallbladder, but the passage of a small stone through the drainage tract following an attack of colicky pain suggests that there was some disease present. Certainly, there was no evidence of back pressure in the gallbladder.

It would seem logical to conclude that this patient recovered from a severe hemorrhagic lesion of his pancreas in spite of operative intervention.

## SUMMARY

The case is reported of a 55-year-old male patient, who was found, at operation, in 1937, to have a massive hemorrhage diffusely involving his pancreas. Following cholecystostomy he recovered, after evidence of severe diabetes during the first month. During the eight years since his operation he has been leading a normal life without symptoms but has had to regulate his diet to maintain his blood sugar at a normal level. The cause of the hemorrhagic process was not discovered but the damage to the pancreas was sufficient to cause severe diabetes during the early postoperative period and permanent, but slight, disturbance of the islet activity since then. The only justification for operation was the uncertainty as to the diagnosis. There is no definite evidence that it was responsible for the patient's recovery. This report has been made because of the rarity of this condition, its severity, and the fact that the patient recovered and has remained well for eight years.

I am indebted to Dr. John Davis Paul for a report on the condition of this patient in recent years.

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# WAR INJURIES OF THE CHEST

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Statistics, recently reported by Carter and DeBakey,[1] indicate that chest wounds comprise from one-fourth to one-third of all battle casualties and about one-twelfth of the wounds of soldiers that survive admission to medical units. The high incidence and seriousness of these conditions have made their treatment a matter of great importance. The Army has been fully cognizant of this and has endeavored to place surgeons with special training and experience in thoracic surgery in all of our Theaters of Operation. That this was done with wisdom has been proved by the relatively low mortality rate for chest injuries in the present war, as compared with all previous wars.[1]

The reports of Carter and DeBakey, and others, covering the incidence, types, complications, treatment, and mortality of chest wounds in the present war have been of great interest and help to the men working in this field. The purpose of this paper is to review the subject with special emphasis on treatment and the physiologic alterations which accompany the pathology of these wounds.

The proper treatment of thoracic wounds demands that the physiologic alterations which accompany them be well understood. These may be due to any of the following conditions: (1) Open pneumothorax, usually associated with "sucking wounds" of the chest wall; (2) tension pneumothorax; (3) surgical emphysema, either superficial or mediastinal; and (4) cardiac tamponade. All, or any, of these may be associated with a chest injury. Therefore, it is most essential that they be kept in mind when a patient with a chest wound is first examined. All of them may be serious and if overlooked may lead to deaths which could have been prevented. The initial treatment of thoracic injuries consists mainly in combatting shock, the proper care of the wound and correcting these physiologic disturbances.

## PATHOLOGY

*Open Pneumothorax.*—The dangers of an open pneumothorax have been well understood for many years. The high mortality which followed early open drainage in the streptococcal empyemas of the last war was later proved to be due to the ill effects of the open pneumothorax that was produced by operation. When this method of treatment was changed and the pleural fluid in the early cases was evacuated by repeated aspirations, rather than by open drainage, the mortality fell from about 50 per cent to about five per cent. Graham and Bell,[2,3] in a series of experiments on animals, showed that the harmful effects of an open pneumothorax are due to pulmonary collapse which, in turn, leads to a decrease in vital capacity, asphyxia and death. Graham and Bell also showed that in the presence of a mobile mediastinum, the effects of

an open pneumothorax are bilateral and that the degree to which the vital capacity is reduced is directly related to the size of the opening in the chest wall. One of the fundamental principles in the treatment of empyema, namely, not to institute open drainage in the early or acute stages of the disease is based on these experiments. When a hole is torn in the chest wall by a shell fragment or bullet, the effect is exactly the same as establishing open drainage in the early or acute stages of an empyema. Air is sucked in through the opening with each inspiration. The intrapleural pressure rises and the expansion of the lung is reduced. In order to compensate, the patient breathes faster and with greater effort, and this, in turn, rapidly leads to exhaustion. Open wounds of this kind, so-called "sucking wounds," should be closed as soon as possible. Experience has shown, however, that closure by suture is inadvisable unless all of the necessary surgery has been completed. When the existing facilities are inadequate for this, or trained personnel is not available, treatment, in general, should be limited to first-aid measures; namely, control of shock, control of hemorrhage, excision of devitalized and soiled tissue, and removal of readily accessible foreign bodies. The wound is then covered with a pad of vaselined gauze. This is either sutured to the skin, or strapped in position with adhesive plaster.[4] In most instances this method will suffice until the soldier can be delivered to a suitable hospital for definitive operating. The vaselined pad is effective not only in preventing the entrance of air into the chest, but also in permitting the escape of air and fluids from the chest. This is an advantage, because, otherwise, serious respiratory embarrassment might result from a tension pneumothorax or an accumulation of blood.

The effects of crushing injuries of the chest which are accompanied by multiple rib fractures may be exactly the same as those of an open pneumothorax. In these cases the reduced pulmonary expansion is due to paradoxic motion of the chest wall at the site of the injury. The more the chest wall is sucked in during inspiration, the less the lung is sucked out and the greater the decrease in vital capacity. Here, again, the patient compensates by breathing faster and with more effort. Treatment of these injuries should be directed toward stabilization of the mobile areas of the chest wall and this is best accomplished by adhesive strapping.

The effects of an open pneumothorax on the circulation are less spectacular, but animal experiments have shown a rise in venous pressure and a decrease in cardiac output. These changes have been attributed to the reduced intrathoracic sucking effect which helps to draw blood to the heart and also to a direct tamponade effect on the heart itself.

*Tension Pneumothorax:* When a lung is pierced or torn, or, more rarely, when a bronchus is lacerated, air may repeatedly be sucked into the pleural cavity during inspiration and trapped. The opening, acting as a ball-valve, allows the air to get in, but does not allow it to get out. Under these conditions, the intrapleural pressure steadily increases and the resulting tamponade effect may reach alarming proportions and seriously interfere with both pul-

monary expansion and the filling of the right side of the heart. This leads to severe dyspnea and, in extreme instances, to acute circulatory failure, evidenced by a falling systemic pressure, a high venous pressure, a weak, rapid pulse, pallor and sweating. In civil practice, this condition, which is known as a tension pneumothorax, is occasionally seen after pneumonectomy or lobectomy, when the closure of a bronchial stump or lung is insecure or gives way in the presence of infection. It may also follow rupture of an emphysematous bulla. It is more likely to be due to laceration of the lung or bronchi by fragments of broken ribs. The immediate treatment is very simple: The pressure can be relieved quickly by introducing a needle through one of the intercostal spaces. A simple method is to use a needle with a flange, which can be readily strapped to the chest wall. If such a needle is not available, a flange can be improvised by using an ordinary cork.[4] The needle is inserted through the cork, which, in turn, is fixed to the chest wall with adhesive strapping. The second intercostal space in the midclavicular line is a convenient location for introducing the needle. If left in position the needle should be connected with a "water-seal."

*Surgical Emphysema.*—Surgical emphysema is of two types, namely, superficial and mediastinal. The superficial variety may result from laceration of the lung by in-driven rib fragments or penetration of the lung by a missile. In either case air escapes into the subcutaneous tissues, either directly from the lung at the site of an adhesion, or indirectly through the medium of an interposed pneumothorax. From the chest wall the air may spread upward to involve the tissues of the neck and face, or downward to the abdominal wall. In extreme instances, even the extremities are involved. The diagnosis is readily established by the crackling sensation which one gets on palpating the involved areas and the air in the tissues is easily recognized on roentgenograms. Fortunately, the condition in itself rarely demands any special treatment because the opening in the pleura usually becomes sealed after a short period of time and the air in the tissues is readily absorbed. If the pleural opening does not close, however, and the condition becomes progressive and causes symptoms, relief should be obtained by introducing a needle into the pleural space for the escape of the air. The recognition of a superficial emphysema is important because it may be an indication of a tension pneumothorax.

Mediastinal emphysema is a much more serious condition because air escaping into the mediastinum does not find a ready outlet and there is serious danger of compression of the great vessels, and even the esophagus. Here the air escapes from a lacerated trachea or large bronchus and tends to spread towards the neck. The condition is readily recognized from a soft swelling in the suprasternal notch and the diagnosis can be confirmed roentgenographically. Radical treatment is indicated only when the symptoms of compression are severe enough to endanger life. Treatment is directed toward relief of pressure. In some instances this can be easily accomplished simply by incising the swelling in the neck. In exceptional instances, a thoracotomy may be

necessary, followed by incision of the mediastinal pleura and suture of the lacerated bronchus or trachea.

*Cardiac Tamponade.*—Cardiac tamponade is a term which is commonly used to refer to acute cardiac compression caused by the rapid accumulation of blood or exudate within the pericardial sac. Since the pericardium is a dense, fibrous, relatively inelastic membrane, it is not distended appreciably by an acute increase in pressure. Observations have shown that from 200 to 250 cc. of fluid in a normal pericardium is a sufficient amount to cause circulatory failure. The pressure of the fluid obstructs the filling of the heart and the blood is dammed-up in the great venous reservoirs of the body. Should the intrapericardial pressure equal the effective venous pressure, the blood can no longer enter the right auricle and death follows. The clinical picture is that of circulatory failure, characterized by a low systemic pressure; a high venous pressure, distant or absent heart sounds; an imperceptible or thready pulse, pallor and diaphoresis. Roentgenograms show a large cardiopericardial shadow with sharply defined edges and fluoroscopic examination reveals a diminution or absence of the normal cardiac pulsations. In chest injuries, the syndrome is caused by intrapericardial bleeding which usually results from a stab wound in the front of the chest to the left of the sternum, in the third or fourth interspace. The source of the bleeding is most likely to be the right ventricle or the anterior descending branch of the left coronary artery. The right auricle, right coronary artery and the intrapericardial portions of the great vessels (all of which lie behind the sternum) are less likely to be damaged.

The treatment of this condition demands the greatest haste. The indications are two: first, and foremost, to relieve the pressure; and, second, to stop the bleeding. The time required for roentgenologic and fluoroscopic examinations might mean the difference between life and death. These examinations, therefore, should be omitted, unless the condition of the patient is obviously such as to permit their being undertaken without danger. Preparation for operation and transfusion should be made at once. Experiments on dogs and preliminary observations on patients, recently reported by Cooper, Stead, and Warren,[5] indicate that the preoperative administration of intravenous fluids is beneficial. If the patient's condition is stationary or improving, one or more pericardial taps might suffice. On the contrary, if the evidence of this is lacking or questionable, it is much safer to expose the pericardium at once, evacuate the blood, and attempt to locate the source of the hemorrhage and control it by suture. When there has been serious loss of blood, one or more transfusions should then be given.

*Hemothorax:* Hemothorax is a very frequent complication of thoracic wounds. According to Davies and Cooper,[6] it occurs in 70 per cent of all chest injuries in modern warfare. It also frequently occurs following crushing injuries of the chest with simple rib fractures and almost always accompanies penetrating wounds. The bleeding may be from the lung itself, but more often comes from the chest wall, and can usually be traced to lacerations

of the intercostal vessels. In World War I the incidence of infection of hemothorax complicating penetrating wounds of the chest was about 25 per cent.[7]

The treatment of hemothorax has been a subject of much discussion. Some have advocated extreme conservation, aspirating only to relieve pressure or pain. Others have advocated aspiration with air replacement and still others, aspiration alone. The latter method, namely, aspiration alone, with a view toward emptying the pleura as quickly and completely as possible, is now widely approved as the treatment of choice. The points that have been made against the conservative treatment of a hemothorax are the following: (1) Blood is a good culture medium and encourages the development of infection and empyema; (2) blood may not be completely absorbed and this, in turn, leads to the development of a so-called fibrothorax with contraction and fixation of both the chest wall and lung; and (3) in war injuries, infection and incomplete absorption of an hemothorax are not uncommon complications, probably because of the great amount of tissue damage that so frequently accompanies the injury.

The injection of air after aspiration is now condemned as being both unnecessary and harmful. The procedure apparently originated with the thought that by keeping the lung collapsed recurrence of bleeding after aspiration would be avoided. This idea is based on the assumption that the source of bleeding is pulmonary, whereas it is now well-known that in the great majority of instances at least the source of bleeding is the chest wall. The method also overlooks the fact that bleeding from the lung tends to cease spontaneously because of the low pressure in the pulmonary circuit. That the method is harmful has been demonstrated by experience accumulated in the present war. Case analyses have shown that the incidence of chronic hemothorax and chronic empyema is higher in patients with hemothorax treated by aspiration and air replacement than in those treated by aspiration alone.

When an hemothorax can not be controlled by aspiration because of clotting, the proper treatment is an early thoracotomy with evacuation of the blood clot. When this is not done the surface of the compressed lung is soon covered by a layer of fibrin, which, in turn, becomes organized and fixes the lung in its compressed state. When this condition exists the treatment should include, in addition to evacuation of the clot, excision of the thickened membrane which prevents the lung from reëxpanding. The membrane is more easily excised in the early stages of an hemothorax. Later, after an interval of two to three months, it becomes more intimately attached to the lung and the plane of cleavage is more difficult to develop. Good exposure for operating, hemostasis, early reëxpansion of the lung and obliteration of the pleural space are of great importance. When satisfactory hemostasis is not obtained it is probably advisable to establish closed, catheter drainage, rather than depend on aspirations, for evacuation of the blood. Otherwise clotting may recur and a second thoracotomy become necessary.

The treatment of chronic hemothorax by excising the fibrous membrane covering the underlying lung appears to have reduced the incidence of chronic

empyema in the present war. Case 1 (Fig. 1) is an example of a satisfactory result. Case 2 is an example of a postoperative, or recurrent, "chronic" hemothorax, for which a second thoracotomy and decortication were necessary. Figure 2 is an example of a chronic hemothorax with areas of calcification in the thickened membrane on the lung.

## TREATMENT OF VARIOUS TYPES OF WOUNDS

Chest cases should have a high priority among battle casualties and taken as quickly as possible to an installation with complete anesthesia and operative facilities, preferably one with personnel experienced in thoracic surgery. Endotracheal anesthesia should be routine in all intrathoracic procedures, and facilities for suction should be at hand. The wounds should not be sutured until all of the surgery, necessary at the time, has been completed. Suturing then should be directed primarily toward closing the pleura. When it is necessary to approximate muscle and fascial layers of the chest wall these structures should be sutured loosely. The skin and subcutaneous tissues should be left open. If the wounds are sutured without thorough débridement, or in the presence of extensive lung damage, infection of the chest wall and pleura is very likely to develop. If the wound is a "sucking" one, a pad of vaselined gauze, which is either sutured to the skin, or strapped in position with adhesive plaster, will prevent the aspiration of air and at the same time permit drainage while the patient is being transported. An accompanying hemothorax should be evacuated as completely as possible with a view toward obtaining early reëxpansion of the lung and obliteration of the pleural space. If there is a delay and infection is already established when the casualty reaches a suitable installation the primary operation should be restricted as far as possible to simple procedures, such as the removal of readily accessible foreign bodies and incisions to maintain drainage of the chest wall and pleura.

*Wounds of the Chest Wall:* The treatment of wounds of the chest wall does not differ from the treatment of similar wounds in other parts of the body. The adjacent skin surface should be cleansed; readily accessible foreign bodies removed; bleeding controlled and all devitalized tissues excised. After this, the wound should be left open, with or without the local administration of one of the sulfonamides. Secondary suture should be done later (after four days) if the condition of the wound permits.

*Perforating Wounds:* The treatment of through-and-through bullet wounds of the chest, which cause slight pulmonary damage and do not injure large blood vessels or other important structures, consists mainly of the treatment of hemothorax. The treatment of hemothorax is discussed under a separate heading. It is well-known that wounds of this type, which are commonly seen in civil life following attempts at suicide, do well. The same is true of similar wounds incurred in combat. When a bullet is deflected from its course by impact with a rib, however, the damage to a lung and to the chest wall at the site of exit may be extensive. Extensive destruction

of tissue may be caused also by shell fragments. Case 3 illustrates some of the complications which may follow a wound of this type.

*Penetrating Wounds with Retained Foreign Bodies:* The common types of retained foreign bodies which have been seen in the present war are shell fragments, bullets, pieces of clothing and splinters of bone. In treating these injuries the risk of the operative procedure which would be required for removal of the foreign body has to be balanced against the risk of complications which are likely to develop if the foreign body is left in place. Experience has shown that pieces of clothing and fragments of bone are especially likely to lead to serious infection and every effort should be made to remove these. On the contrary, metallic foreign bodies are well tolerated. Nevertheless, it is felt that these should be removed also when they are large (diameter of 2 cm. or more), causing symptoms, free in the pleural space with hemothorax, or, because of their position, considered to be a threat to vital structures such as the heart, esophagus, and large blood vessels. It is generally agreed that unless there is immediate danger of serious complications only those foreign bodies that are readily accessible should be removed at the initial operation, preferably done as soon as possible after the injury is received. Timing of a secondary operation, for removal of foreign bodies which are not disturbed at the initial operation, but which are removed later because of their size or position, is of great importance. It is considered safer to postpone the secondary operation for at least two weeks, and in many instances longer, to allow the patient time to recover completely from the loss of blood and the acute effects of trauma. Cases 4, 5 and 6 are presented as examples of penetrating wounds of the chest with retained foreign bodies.

*Thoraco-abdominal Wounds:* Whenever a missile penetrates the thoracic cavity the possibility of its having traversed the diaphragm and entered the abdomen must always be borne in mind. This is particularly important if the thoracic wound is low, in the region of the diaphragm. Roentgenograms of the abdomen as well as the chest should regularly be taken. When operation is being planned, careful consideration should be given to all the facts relative to both the thoracic and abdominal wounds. There is no standard procedure that can be applied in all cases. Certain general principles, however, do apply: (1) Endotracheal anesthesia is vitally important in cases of this kind; (2) the hemothorax which is almost certain to be present, should be aspirated before operation; (3) a celiotomy should always be done and the incision should be large enough to permit examination of all of the abdominal viscera; (4) "sucking wounds" of the chest must be closed early in order to save life, and in most instances take priority over the abdominal exploration; (5) the possibility of a diaphragmatic hernia must be considered; and (6) a foreign body suspected of being embedded in the liver may be more easily reached by a transthoracic approach which is extended through the diaphragm than by a celiotomy. Case 7 is an example of a thoraco-abdominal wound.

*Infected War Wounds of the Chest:* The treatment of infected war wounds of the chest may be briefly summarized as follows: (1) Pleural and

pulmonary suppuration are forestalled by early operation (within six to ten hours), removal of foreign bodies, local and systemic use of the sulfonamides or penicillin, and leaving the superficial layers of the wound in the chest wall open; (2) infected hemothorax in the early stages is properly treated by aspiration. Thoracotomy with rib resection (open drainage) should be postponed until the pleural exudate is definitely purulent. This allows time for localization of the pleural infection, avoids the dangers of an open pneumothorax, and reduces the risk of a large or a total empyema; and (3) pulmonary or pleuropulmonary suppuration secondary to retained foreign body should first be treated by drainage. Extensive operative procedures for the removal of foreign bodies should be avoided in the presence of active infection. Lobectomy in wounds of this type when indicated should be postponed, if possible, until the infection is brought under control.

## CASE REPORTS

**Case 1.**—A commander of a tank company was wounded in action, July 12, 1944, sustaining a penetrating shell fragment wound of the left chest, with fracture of the eighth rib. Treatment overseas consisted of débridement and closure of the wound on the day of injury and two thoracenteses. When the patient arrived at the Halloran General Hospital, September 1, 1944, roentgenograms of the chest showed an encapsulated hemothorax on the left and a shell fragment overlying the 7th intercostal space near the vertebral column. Operation, October 30, revealed a cavity containing 150 cc. of old blood clot, and a rigid, fibrous membrane covering the adjacent part of the lung. Operation consisted of evacuating the blood clot and excising the membrane, following which the lung was reëxpanded and the wound closed without drainage. Roentgenograms of chest on the 15th postoperative day showed complete reëxpansion of the lung. Removal of the shell fragment was not advised.

COMMENT: This case illustrates the successful treatment of a small, chronic hemothorax by decortication of the lung (Fig. 1).

**Case 2.**—This soldier sustained a perforating shell fragment wound of the chest, March 29, 1945, the fragment lodging in the soft tissues of the back at the level of the second lumbar vertebra. An effort to aspirate a complicating hemothorax was not made until April. When the soldier came under our care, in June, examination showed contraction and marked limitation in motion of the right side of the chest. Roentgenograms showed an encapsulated hemopneumothorax in the right axilla. Operation was delayed by an attack of malaria until July 21, 1945. Exploration on this date revealed a cavity of approximately 300 cc. and, as in Case 1, the underlying lung was covered by a rigid, fibrous membrane. This was excised and, after inflating the lung, the wound was closed without drainage. The postoperative course was complicated by a second hemothorax which could not be controlled by aspiration because of clotting. Consequently, the chest was reopened on August 13, 1945, and after evacuating the blood clot the lung was decorticated a second time. Following this operation the wound was not sutured, but closed temporarily with a silk and gauze tampon which was left in place for seven days. It was considered safer not to suture the wound after the second operation because of the danger of infecton. The cavity finally closed on December 1, 1945.

COMMENT: The initial operation on this soldier was unsuccessful because the blood which accumulated in the pleura later clotted and could not be removed by aspiration. The danger of this complication is always present

1-A



1-B





1-C

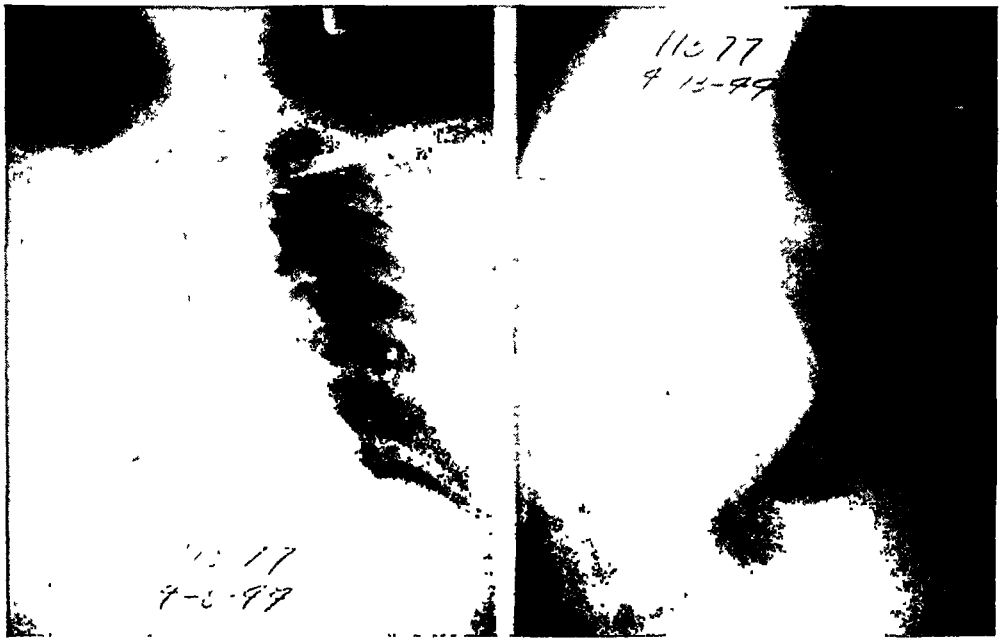
FIG. 1.—Case 1: (A) Roentgenogram of chest showing encapsulated hemothorax on the left and metallic fragment in the 7th left intercostal space near the vertebral column.

(B) Roentgenogram of chest 15 days after evacuation of blood clot and decortication of the lung. Lung completely reëxpanded.

(C) Photograph of patient on the 15th postoperative day, showing primary healing of the wound.

after a decortication of the lung, and when postoperative oozing is profuse and hard to control, it is perhaps safer to establish and maintain some form of closed drainage until the lung has reëxpanded and closed the pleural space.

**Case 3.**—A 24-year-old soldier was struck by a machine gun bullet on September 22, 1944. The bullet entered the left chest posteriorly between the scapula and spine and emerged anteriorly in the midclavicular line, about two inches below the clavicle, lacerating the lung and shattering the posterior portion of the fourth rib and the anterior portions of the second and third ribs. Both wounds were sutured about 30 minutes after



2-A 2-B

FIG. 2.—(A) Roentgenogram of chest showing a large, encapsulated hemothorax on the right side with areas of calcification in the thickened membrane on the surface of the lung. This was an unexpected finding in a soldier who was evacuated from the Aleutians in the Spring of 1944. He gave no history of an injury to his chest but stated that he had been knocked down by an automobile on August 31, 1941. No roentgenograms of the chest were taken at that time. This soldier refused operation.

(B) Lateral view of the same patient.

injury. On the following day both wounds were reopened, the lung was sutured and, after débridement, the wounds were closed a second time. Subsequent to this the anterior wound became badly infected and the soldier developed a left empyema. On admission to the Halloran General Hospital, in December, he had lost 38 pounds. The left chest was markedly contracted and fixed. The anterior wound was still draining and through the opening in the chest wall one could see a large defect in the lung with multiple fistulae. A drainage tube entered a residual empyema cavity at the site of a previous rib resection. This soldier had not been assigned to our hospital for definitive care and, in accordance with Army procedure, had to be transferred to another institution (Fig. 3).

**Case 4.**—A 21-year-old soldier was struck in the right chest by a machine gun bullet on July 28, 1943. The wound healed satisfactorily, and a complicating hemothorax cleared without aspiration. After this the soldier had no symptoms referable to his chest until June, 1944, when he coughed up a small amount of bright red blood. The hemoptysis

recurred in September. Roentgenograms of the chest showed a 25-caliber bullet situated posteriorly on the right side at the level of the tenth intercostal space. Films made after the instillation of lipiodal showed no evidence of bronchiectasis. The bullet was removed on October 13, 1943. The space which it occupied communicated freely with the bronchial tree and contained a small amount of necrotic material, culture of which revealed an *hemolytic Staphylococcus aureus*. Convalescence was satisfactory except for a small empyema which healed rapidly after rib resection and drainage.

COMMENT: This case demonstrates that a foreign body (in this particular instance, a machine gun bullet) may be embedded in a lung for many months before causing symptoms. The history suggests that the hemoptysis was secondary to infection due to the *hemolytic Staphylococcus aureus* (Fig. 4).

**Case 5.**—A soldier received multiple penetrating wounds of the left chest on July 28, 1944. On July 30, 1944, all wounds were débrided and readily accessible foreign bodies were removed. The soldier arrived at Halloran General Hospital, October 9, 1944, with



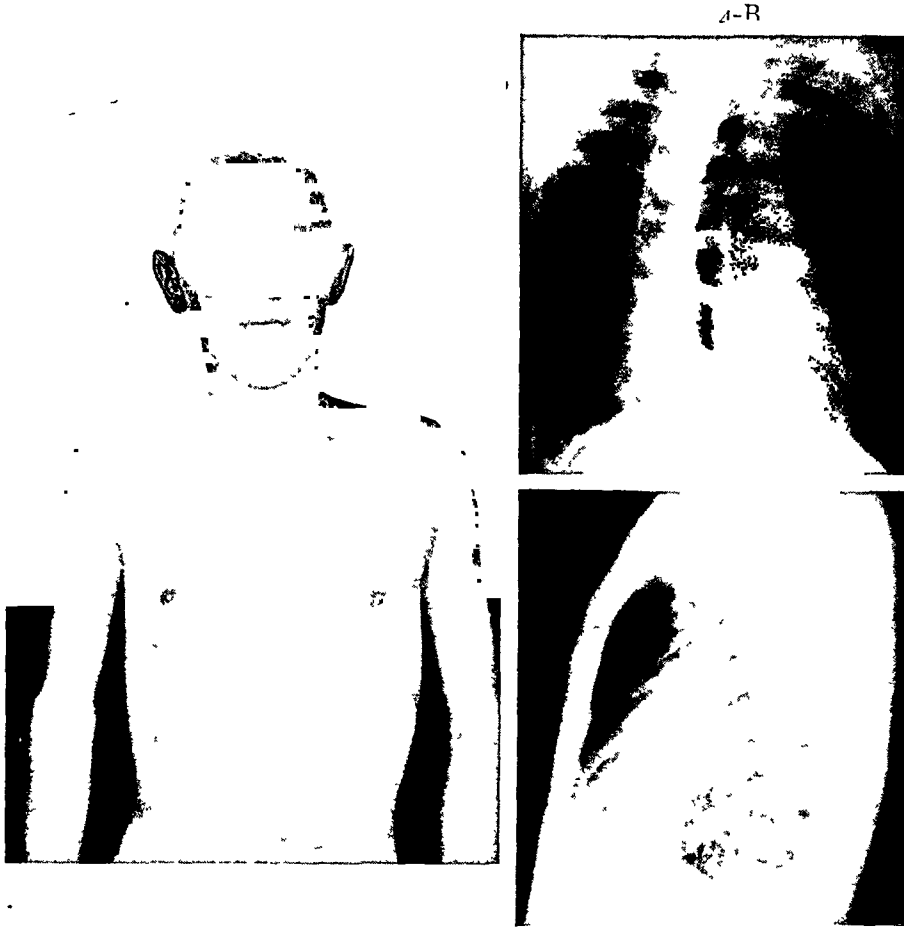
3-A 3-B

FIG. 3.—Case 3: (A) Photograph made on January 25, 1945, showing the extreme degree of malnutrition and the contraction of the left chest. The anterior wound below the left clavicle represents the point of exit of the bullet. The wound in the axilla is the site of the rib resection which was done on October 10, 1944, and leads into the dependent part of the empyema cavity.

(B) Photograph showing the wound in the left scapular region, point of entrance of the bullet. This wound was completely healed when the patient came under our care on December 27, 1944. Note the scoliosis secondary to the contraction and fixation of the left chest.

a temperature of 103° F., pulse 120, and respirations 30 He was pale and weak and showed evidence of considerable weight loss. R.B.C. 2,270,000; W.B.C. 3,900, and Hb. (Sahli) 7.5 Gm. Roentgenograms of the chest showed a metallic fragment, measuring about 2 x 3 cm, in the posterior portion of the left lung at the level of the tenth dorsal vertebra. The patient received penicillin, repeated blood transfusions and vitamin therapy. A subcutaneous abscess in the left scapular region was drained, October 19, 1944, and in

addition to 25 cc. of purulent material three pieces of woolen shirt were evacuated. Culture of the exudate showed *B. coli* and *nonhemolytic Staphylococcus aureus*. After this the temperature quickly dropped to normal and convalescence was satisfactory except for an attack of malaria which responded quickly to atabrin. By the middle of November the patient had gained 19 pounds. R.B.C. 4,870,000; W.B.C. 5,850, and Hb. 14.5 Gm. The time was considered opportune for removal of the metallic fragment in the left lung, but inasmuch as the soldier had now become transportable and had not been assigned to this hospital for definitive care, he had to be reported to the Registrar for transfer to another institution.



4-A 4-C

FIG. 4.—Case 4: (A) Photograph of the patient taken after admission to the Halloran General Hospital, showing the scar at the point of entrance of the bullet.

(B) Roentgenogram made on October 4, 1944, in the left anterior oblique position, showing the bullet in the right chest lying opposite the 10th intercostal space.

(C) Lateral roentgenogram showing the bullet to be situated posteriorly just above the dome of the diaphragm.

COMMENT: This case is another example of a metallic foreign body being retained within the lung for many months without causing symptoms. Furthermore, it shows the ineffectiveness of penicillin in controlling a suppurative process in the presence of tissue damage, foreign bodies and a nonsusceptible organism (Fig. 5).

**Case 6.**—This patient was struck by a shell fragment, November 7, 1944, sustaining a penetrating wound in the right supraclavicular region. He recovered rapidly from the effects of his injury and felt well within a short time. When he came under our care in May, 1945, he was in excellent condition and had no complaints. Roentgenograms of the chest showed the shell fragment in the right upper lobe and an healed fracture of the right second rib. The shell fragment was removed in September, 1945, and cultures taken from the cavity which it occupied showed *nonhemolytic Streptococcus* and *nonhemolytic Staphylococcus aureus*. Penicillin was given postoperatively. Convalescence was uneventful except for a small pleural effusion which cleared without aspiration.



5-A 5-B

FIG. 5.—Case 5: (A) Roentgenogram of chest taken on October 12, 1944, showing a large metallic fragment in the left chest at the level of the 10th dorsal vertebra. The smaller fragment is outside the thoracic cavity in the tissues of the axilla.

(B) Lateral view, also taken on October 12, 1944, showing the metallic fragment to be situated posteriorly.

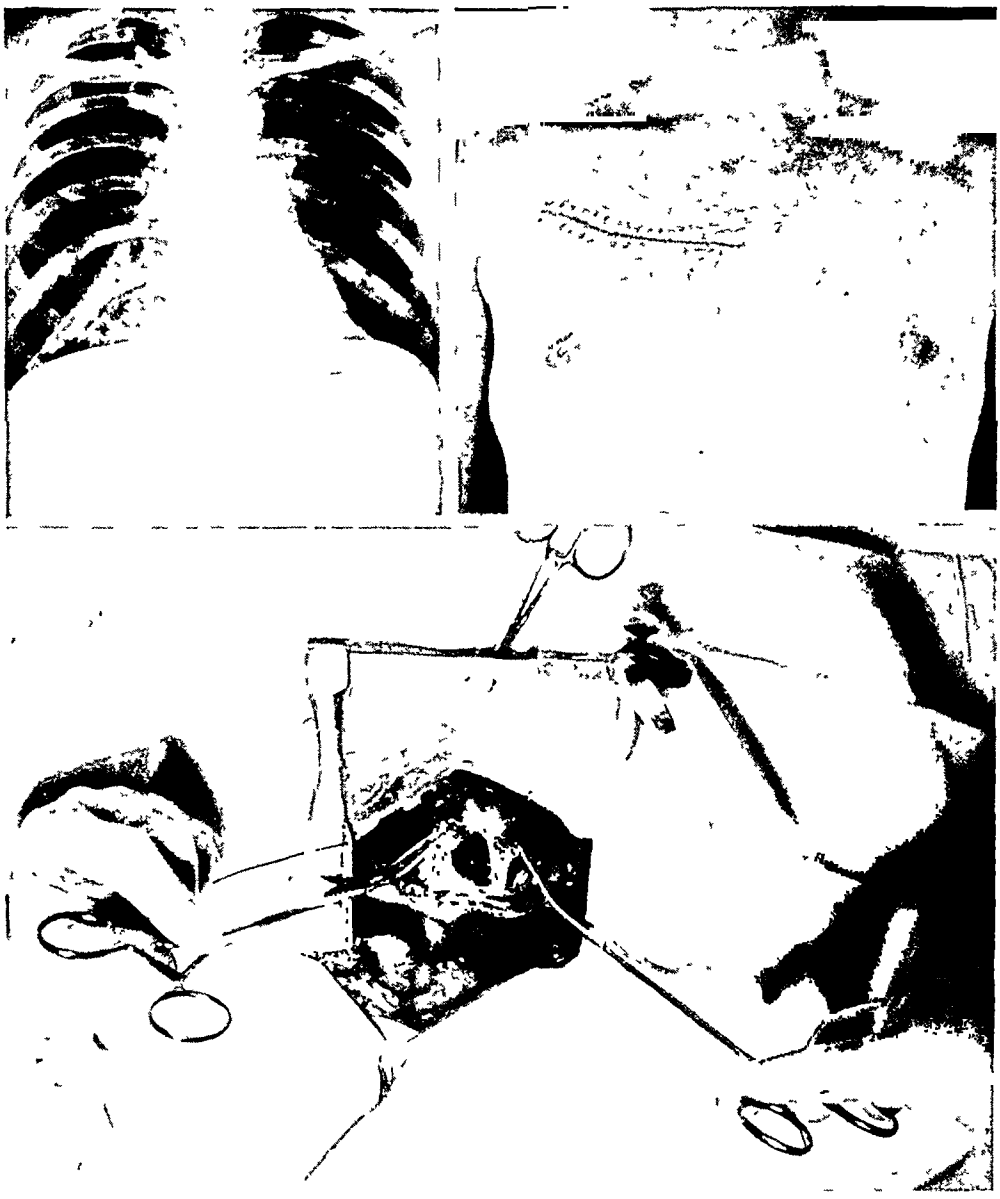
COMMENT: This case is another illustration of a metallic foreign body being retained in the substance of the lung for many months without causing symptoms. The fact that this man did not develop a postoperative empyema may have been due to the penicillin (Fig. 6).

**Case 7.**—A soldier was wounded accidentally when a 60-mm. mortar shell fell short and exploded at 0930 hrs., May 2, 1944. He was struck by a shell fragment in the left lower chest and, on admission to a General Hospital, about two hours later, complained of severe, upper abdominal pain. Examination showed moderate shock, with rigidity and tenderness in the upper abdomen, and beginning dullness in both flanks. There was a wound approximately 15 cm. long in the midaxillary line, left, at the level of the tenth intercostal space, with a portion of the spleen herniating through the wound. Roentgenograms of the chest and abdomen were reported negative, both for pneumothorax and foreign bodies.

The patient was given plasma, and the abdomen was explored three hours and fifteen minutes after injury. The operative findings included a ruptured spleen, a 7-cm. rent in the left leaf of the diaphragm, two perforations of the stomach, a puncture wound on the inferior surface of the left lobe of the liver and blood and gastric contents in the peritoneal

6-A

6-C



6-B

FIG. 6.—Case 6: (A) Roentgenogram made May 23, 1945, showing the metallic shell fragment in the right upper lung field.

(B) Photograph made at operation on September 28, 1945. Traction on the wound edges has produced the appearance of a cavity which did not exist. The fragment can be seen in the depth of the space.

(C) Photograph of the patient made October 8, 1945, ten days after operation, showing the operative wound over the second right interspace.

cavity. The spleen was removed, and after suturing the perforations of the stomach and the rent in the diaphragm the wound was closed in layers without drainage. The puncture wound on the under surface of the liver was not explored. The wound of the chest wall was then débrided and closed. Subsequent to this the soldier developed a left empyema. He came under our care, September 19, 1944, with a discharging sinus at the site of a previous rib resection. The sinus was excised and a residual empyema cavity unroofed on September 25. Microscopic examination of the sinus tract showed "numerous tubercles with central necrosis and borders of granulomatous tissue." This procedure was also followed by a persistent sinus. On subsequent investigation this was found to connect with a bronchus and to extend through the substance of the lung to the diaphragm apparently along the course taken by the shell fragment. The soldier had to undergo two additional operative procedures before the tract was completely excised and permanent healing of the wound obtained. Examination of the tissue removed at these operations confirmed the diagnosis of tuberculosis.

COMMENT: This case is of particular interest because of the development of tuberculosis of the tissues at the site of injury. So far as is known this patient had never shown any previous manifestations of this disease. The complication supplies an adequate explanation for the chronicity of the process and the repeated failures to obtain satisfactory healing despite the establishment of adequate drainage. A satisfactory result was finally obtained only when all of the disease had been excised and the resulting defect closed by the approximation of well-nourished tissues.

Primary celiotomy was obviously the correct procedure and it seems wise that no effort was made to remove the shell fragment which was embedded in the liver. In consideration of the soldier's extensive injuries and condition at the time of operation, it also seems wise that the chest was not explored. Primary closure of the superficial layers of the wound of the chest wall after débridement, however, was contrary to the teachings of most military surgeons at the present time.

## CONCLUSIONS

In conclusion, it would seem appropriate to direct attention briefly to the rapid advancement which has been made in the field of thoracic surgery since World War I. The dangers of open drainage in the early stages of empyema were appreciated before World War I was over, and the fall in mortality rate which followed has already been mentioned. After this, the means of controlling respiration by positive pressure were perfected and this made it possible to undertake with safety deliberate and meticulous operating inside the thoracic cavity. This soon led to a rapid advance in surgical technic and within a very short time operations like lobectomy and pneumonectomy (both of which had been tried before but abandoned because of high mortality) were being undertaken again and with a very reasonable mortality. In the past six or eight years the operative mortality for lobectomy has fallen to about two or three per cent and more recently esophagectomies, pericardiectomies, suture of heart wounds, ligation of patent ductus arteriosus and excision of intrathoracic neoplasms have become a daily occurrence. So there was good reason

to expect that the results of treatment of chest injuries in World War II would be superior to those of World War I. That this is true is apparent from the relatively low mortality rate for chest injuries and the low incidence of chronic empyema.

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# NOTES ON OPERATIVE TECHNIC IN NEUROSURGERY

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THE MINOR PRINCIPLES of operative technic to which a surgeon adheres are the product of his surgical inheritance, the traits of his character and his capacity for imitation. Neurosurgeons have borrowed freely from each other and I have learned much from my own colleagues, William Cone and Arthur Elvidge. Consequently, no claim is made to originality in this field. But it was Professor Allen Whipple who first called my attention to the importance of these minor principles of surgical technic. The following notes are, therefore, set down here by his grateful pupil and friend.

*Classical Technic.*—Harvey Cushing was the first superlative technician among neurosurgeons. Fastidious care in every detail of opening and closure of the skull was perhaps his greatest contribution to the operative technic of craniotomy. Fastidiousness was his by inheritance from Professor Halsted and as an inborn characteristic.

He made a habit of closing the dura after an osteoplastic craniotomy without drainage. On the other hand, he left the dura open under a subtemporal decompression and after a suboccipital craniotomy. He almost never drained a craniotomy wound. But he took great care to close the galea aponeurotica with a careful line of interrupted fine silk sutures. This was a technical maneuver of the greatest importance to which almost all neurosurgeons still adhere because it relieves the skin sutures of tension and prevents fistular drainage.

But Cushing found it necessary to puncture the scalp and aspirate fluid from beneath the aponeurosis frequently during the first ten postoperative days. That was his way of relieving tension on his unfastened bone flap and his undrained scalp, and it worked well in his hands, however tedious the dressings.

This set of technical procedures might be called the classical pattern. When one detail is altered many others must be changed. But to continue to adhere to it would be to miss the opportunity for advance.

*Drainage.*—A rubber drain through a small scalp incision, "stab wound," not far from the incision for an osteoplastic craniotomy, may serve to allow fluid to escape from outside the dura. If the inner end of the drain is placed inside the dura, fluid and air are allowed to escape from the intradural as well as the extradural space.

Such a drain should be covered with gauze and over that a layer of impermeable protective tissue, the borders of which are brought down to the sterile scalp surface on which sterile vaseline may be placed. This avoids any danger of retrograde contamination provided the drain is withdrawn within one to

three days. This type of drainage makes it possible to fasten the bone flap at one or two points with steel or tantalum wire if it seems desirable.

*Cosmetic Note.*—The bur holes of the bone may be covered with small round disks of sheet tantalum. This is preferable to replacement of bone buttons or bone fragments, for these implants shrink with the passage of years and most surgeons are distressed by the dimpled foreheads or, even worse, the dimpled bald heads that return to their consulting rooms from time to time.

*Lumbar Puncture.*—When bone flaps are fastened with wire they reunite with the surrounding bone of the skull much more rapidly and with less bone atrophy. But if the removal of tumor or scar has been so small as not to compensate for postoperative brain swelling then lumbar puncture, carried out more or less frequently, may become necessary in order to decrease intraventricular pressure temporarily. Punctures are rarely needed as long as drainage is used.

The old fear of lumbar puncture is no longer justified, provided a surgeon understands the syndromes of (1) midbrain compression due to temporal lobe herniation into the incisura tentorii (enlarging pupil and loss of reaction to light and failing consciousness, *etc.*); and (2) bulbar compression due to herniation of cerebellum into the foramen magnum (slowing pulse and slowing irregular breathing, *etc.*).

*Aseptic Meningitis.*—This is a term which may be applied to the meningismus and fever associated with the continuing escape of fluid from an operative field into the subarachnoid spaces at the base of the brain, the basal cisternae. Elevation of temperature, because of this, often continues for a week or two after operation. But it may persist for many weeks as a continuous state or as a recurring phenomenon separated by several days of freedom from symptoms. In the recurring type of aseptic meningitis there is sudden headache, fever, leukocytosis in the cerebrospinal fluid and nuchal rigidity.

The most frequent cause of persistent aseptic meningitis is an opening between one of the ventricles and the field of a large operative procedure. Through such an opening into the ventricle the fluid from about the operative blood clot passes through the ventricular system and into the basal cisterns. The second most frequent cause is a wide opening between cisterna magna and operative site.

To prevent this irritative state, care should be taken not to open through the ependymal wall of a ventricle. This is usually not difficult. If, however, a large opening is made into the ventricle the ependymal lining may be closed by a few loosely tied silk sutures. It is helpful to place fibrin film or a strip of gelatin sponge over the rent in the ependyma so as to be included within the sutures when they are tied.

In the posterior fossa, however, it may be impossible to prevent opening the arachnoid covering of the cisterna magna. But when the site of operation is the cerebellopontile angle care should be taken to make only a small decompressive opening in this arachnoidea which covers the cisterna magna.

*Dural Defects.*—When it seems advisable to close a dural defect after a

supratentorial craniotomy it is practically never necessary to resort to the use of a fascial transplant from an incision in another part of the body. Instead of this it is a simple procedure to split the outer layer from the inner layer of adjacent intact dura and to use the outer layer to fill in the defect. If this is not convenient or if the dura is very thin, the epicranium may be removed from adjacent skull and used as a transplant. These procedures provide a satisfactory dural substitute which is preferable to prepared membranes.

*Decompression.*—Subtemporal decompression by means of an opening in the dura over one temporal lobe, so that the brain may bulge outward against the elastic wall of the temporal muscle, still has a restricted field of usefulness, but it is an extremely small field. Decompression of the brain by means of removal of an expanding blood clot or tumor is a very much better procedure, for this removes the cause. In case it is not enough, internal decompression may be employed. By this term is meant the removal of relatively dispensable brain tissue.

For example, one frontal pole or the temporal lobe of the nondominant hemisphere may be removed, and even on the side of the dominant hemisphere the anterior end of the temporal lobe, *i.e.*, 4 to 5 cm. back from the tip of the lobe, may be removed without fear of aphasia.

Improvements and modifications of technic come each year. Men who are young in years, or in mind, are apt to accept them eagerly. Others are more cautious; but nothing can replace the rules of delicate handling of tissue introduced by Halsted.

New methods are not necessarily better methods, and the safest guide to progressive modification is an understanding of the basic principles of intracranial physiology and of wound healing.

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# POSTERIOR CORDOTOMY FOR RELIEF OF PHANTOM LIMB PAIN

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PHANTOM LIMB PAIN, as distinguished from phantom limb sensation or the pain due to sensitive neuromata of an amputated stump, is fortunately rare, for it constitutes a most difficult therapeutic problem. Various procedures such as revision of stump neuromata, neurectomy, rhizotomy, spinothalamic tractotomy,[3] and psychotherapy too often fail to afford relief. Extirpation of the appropriate sensory area from the cerebral cortex, while effective,[4] is open to the serious objection of potential postoperative epilepsy. Prefrontal lobotomy[18] is open to the same objection, plus the additional hazard of postoperative personality changes.

Another procedure has, therefore, been carried out, consisting of posterior cordotomy; that is, section of the posterior column and adjacent substantia gelatinosa of that part of the cord serving the amputated extremity. This procedure entails a minimal risk of postoperative complications, since none of the spinal cord is cut except the portion rendered unessential by virtue of the amputation.

By way of preface it should be stated that, in contradistinction to phantom limb *pain,* phantom limb "sensation" or "impression" is experienced by most amputees.[4, 6, 7, 8, 13] The absent member seems intact, numb, and fixed in one position as a rule. Despite initial posttraumatic discomfort in some cases, such patients usually become accustomed to this sensation, so that it does not constitute a therapeutic problem. Some amputees are also subject to acute lancinating or shocking pains whenever a sensitive neuroma is touched, jarred, or compressed.[8] This condition is not characteristic of true phantom limb pain, nor is the latter always reproduced by electrical stimulation of neuromata.[8] Relief of neuroma pain may be afforded by revision of the offending nerve end by resection, ligation,[7, 8] or injection with alcohol or formalin.[5] When the condition of the wound precludes local surgical intervention, it may then be necessary to resort to neurectomy at a point proximal to the stump, or to dorsal root section through an hemilaminectomy.

True phantom limb pain, occurring in approximately 6 per cent of all amputees,[7, 8] is severe, unremitting, and may be of two varieties, either of which may overshadow the other in severity—(1) burning pain; and (2) cramping pain.

The burning quality of phantom limb pain resembles that of causalgia[12, 16] and other conditions associated with neurovascular dysfunction.[20] For this reason, plus the fact that neurovascular pathology has an extremely high incidence in cases suffering phantom pain,[7] it may be postulated that the burning quality of phantom limb pain is primarily due to neurovascular and associated autonomic disturbances. This view is substantiated by the fact that sympathectomy has relieved phantom limb pain of this variety.

Certain patients, however, complain chiefly of the second, or cramped posture type of pain,[3, 4, 6, 13] which seems to clamp the limb in a tight, fixed position. Since this variety of pain seemed closely allied with disturbed proprioception, it was felt that proprioceptive impulses arising from foci of irritation in the spinal cord,[9] might be responsible for its perpetuation. This supposition is based on the fact that, in certain circumstances, nonpainful stimuli can produce painful reactions and sensations by the process of reënforcement[21] or facilitation.[14] The posterior column conveys the bulk of proprioceptive impulses from spinal cord to midbrain and thalamocortical levels.[15]

Posterior cordotomy was, therefore, carried out in the three patients reported below, with the original intention of sectioning only the posterior column related to the phantom limb. The planned procedure was modified, however, as described in the case reports.

## CASE REPORTS

**Case 1.**—G. B., age 24, was wounded by multiple high explosive shell fragments in the left shoulder November 29, 1944. Amputation at the left shoulder was performed the same day. The patient then suffered marked discomfort continuously throughout the phantom limb, the discomfort being characterized by a sensation of persisting severe muscle cramp that was not only painful but seemed to maintain the limb in a fixed position, as if the forearm were flexed at 90 degrees and the fingers were held in a semi-clenched posture. An associated burning pain was slightly relieved by sympathetic block.

*Operation.*—December 12, 1945: Local anesthesia (1% procaine). Hemilaminectomy; posterior cordotomy (section of fasiculus cuneatus and substantia gelatinosa, left (at C5 and C6).

The left fasiculus cuneatus was transversely divided with a small scalpel blade to the depth of 3.5 mm. just below the 5th cervical laminal arch. On questioning the patient on the table, it was then found that the cramped sensation in the phantom hand was only partially relieved. Therefore, the same procedure was carried out 2.0 cm. distal to the first section, whereupon the patient stated that his original discomfort was almost completely relieved. It should be emphasized that the cord section was carried 2.5 mm. beyond the *lateral* margin of the posterior column, thus, passing through the substantia gelatinosa and part of the dorsal horn where local sensory nerve roots enter the cord and give rise to synaptic and collateral connections.

Following operation there was lasting though not complete relief of the cramping pain. The patient no longer looked anxious and apprehensive, but cheerful and relieved. Three months after operation he had gained 15 pounds, and was on his way to go home and to work.

COMMENT.—It is of interest that after the cordotomy he became aware of a persisting sense of numbness in the phantom hand, without apparent change in its position from the preoperative status. No postoperative sensory, motor, vasomotor, or reflex alterations could be elicited in the opposite upper extremity or in either lower extremity, nor was there a Horner's syndrome. However, from the level of the clavicle to the groin on the left (operated) side, it was noted that application of cool or warm objects to the skin produced an exaggerated and disagreeable sensation of cold and warmth, respectively, causing the patient to flinch. Pin-prick was not felt as acutely as in unaffected areas, and there was a constant sense of mild numbness and stiffness throughout this

area, although no impairment in perception of cutaneous figure-writing or vibratory or positional sensation could be found. These subjective and objective dysesthesias gradually disappeared during the course of the first eight weeks after operation.

**Case 2.**—M. S., age 31, was wounded by mortar shell fragments, May 25, 1945, so extensively that the entire left arm had to be amputated at the shoulder on the same day. The wound healed poorly and pus drained intermittently for several months. When examined, December 1, 1945, the stump was well healed, but the patient complained of a constant severe, tight cramp-like sensation in the phantom hand which seemed semiclenched. In addition, he had trigger areas in the stump which, when touched, accentuated his cramping pain and also produced a shooting, burning type of pain along the phantom arm. Revision of stump neuromata, sympathetic ganglion block, and, finally, section of the trunks of the affected brachial plexus were successfully performed, without significant benefit. A posterior cordotomy was, therefore, performed at the patient's request.

*Operation.*—December 12, 1945: Local anesthesia (1% procaine). The same procedure, at the same levels, was carried out as in Case 1. Almost complete relief was experienced immediately after the operation, but within 36 hours there was considerable return of the original pain, lasting improvement being estimated by the patient at approximately 20 per cent. The hand seemed to be in the same position as before operation; there was relief of the preoperative sensation of tightness, but not of the cramp.

Postoperatively, he noted a sense of stiffness over the entire left thoracic region from the clavicle to the 11th rib, with distortion of thermal and pain perception similar to that experienced by Case 1. There was no other postoperative neurologic change.

It is of interest (see discussion) that this patient had also been wounded in the region of the right or opposite brachial plexus, and sometimes suffered pain along the distribution of the right ulnar nerve. At such times, accentuation of the phantom limb pain occurred after as well as before cordotomy. He also observed that shaving the left side of his face induced a "pulling" sensation along the inner aspect of the left arm.

Three months postoperatively the phantom hand was still free of the preoperative sensation of tightness, though cramp-like pain persisted in the shoulder. The imagined posture of the phantom limb remained unaltered.

Since the burning pain continued, a high left dorsal sympathectomy was done (Smithwick procedure) on March 20, 1946. This afforded no additional relief, and it was, therefore, concluded that more drastic measures would probably be necessary, such as cortical extirpation.

**Case 3.**—L. K., age 25. In May, 1945, a very heavy timber dropped on the left arm, causing such a severe injury that the arm had to be amputated at the shoulder. Following amputation the patient experienced acute cramping and burning pains in the phantom hand, as well as acute hyperesthesia over the left pectoral region. Repeated sympathetic blocks failed to afford relief. It was felt, therefore, that section of the appropriate dorsal roots, rather than sympathectomy, offered the best chance of relief. On October 8, 1945, the spinal cord was exposed from C 5 to Th. 4, through an hemilaminectomy. The dorsal roots and portions of the ventral roots of C 6, 7, 8 could not be identified, having been avulsed at the time of the injury. Accordingly, it was possible to divide only the dorsal roots of C 5, Th. 1, 2, 3 and 4. Following this procedure there was almost complete relief of pectoral hyperesthesia, but only partial relief of phantom limb pain. At the insistence of the patient, therefore, a more radical procedure was undertaken.

*Operation.*—February 10, 1946: Endotracheal gas-oxygen-ether anesthesia. (1) Posterior cordotomy at C 5, left. (2) Sympathectomy, Th. 2-4, inclusive, left. The double procedure was carried out in the hope of dealing both with the cramp-like and also the burning type of pain.

Following operation this patient was comfortable for the first time since his injury. For approximately 14 days after cordotomy hypalgesia and thermal hyperesthesia were noted over the left thorax from the clavicular level to Th. 8. The phantom fingers seemed to be in the same posture one month after the combined operation, as before, but the hand now seemed to be attached to the shoulder instead of the wrist. The skin over and around the stump was dry; there was slight weakness of the peroneal muscles of the left leg and slight diminution of vibratory and position sense in the left foot, plus some reduction of pain and temperature perception over S 3-5 on the right. These signs were rapidly clearing up, and were attributed to edema of the left side of the spinal cord. In fact, this patient considered his last operation so successful that he recommended it to two fellow sufferers.

Discussion.—Posterior cordotomy alone relieved one patient (Case 1) of cramping pain sufficiently to be considered therapeutically worth while. Another patient (Case 2) was only partially relieved by cordotomy, and subsequent sympathectomy afforded no further relief, so that neither procedure proved adequate in this instance. In the third patient (Case 3), whose relief proved most satisfactory, posterior cordotomy and sympathectomy were performed at the same time.

Since all these patients had been subjected to previous procedures (without benefit), the mere fact that surgery was undertaken can scarcely account for their improvement following posterior cordotomy. It is significant that spinothalamic tractotomy has not proved successful in this type of case.[3]

Transection of the dorsal column serving the amputated limb did not appreciably alter the imagined posture of the limb. This observation supports the view that imagined posture is a function of sensory complexes (probably thalamocortical) above the spinal level,[4, 6, 13] due to a "reverberating circuit."[11]

Alleviation of cramping pain by posterior cordotomy may be due, in part, to section of the posterior column, and, in part, to reduction of sensory impulses other than proprioceptive (a) by section of afferent fibers in the substantia gelatinosa; and (b) by interference with afferent collaterals running in, or close to, the substantia gelatinosa; that is, internuncial fibers[15] in the tract of Lissauer.

The fact that the cordotomy had to be extended into the substantia gelatinosa at two levels before significant relief was noted (Cases 1 and 2) substantiates the first view. The postoperative hypalgesia and thermal hyperesthesia, remote from the level of cordotomy in all three cases, supports the second view, for such an effect must have been due to section of ipsilateral, intersegmental sensory collaterals, since the spinothalamic tract serving the affected dermatomes lay in the opposite, untouched quadrant of the cord.

Since posterior cordotomy alone, or in conjunction with sympathectomy, diminishes phantom pain, it may be postulated that these procedures reduce the influx of abnormal impulses tending to maintain hyperactivity (by rein-

forcement) of suprasegmental circuits, such as the thalamocortical relays. Wolff comes to a similar conclusion in regard to other types of pain: "—— that reinforcement in certain instances does occur within the cortex is established."[21]

From the case studies presented above, it appears that the specific type of pain depends in some degree on the predominating type of abnormal "reinforcing" impulses. That is, impulses of predominantly proprioceptive character tend to perpetuate cramped-posture pain, while those of autonomic origin seem more closely related to the production of a burning type of pain. The severity of pain, on the other hand, to some extent seems related to the quantity of ascending impulses of various types, as judged by the fact that section of the substantia gelatinosa, and the various fibers therein, seemed to contribute to the relief of pain. In other words, dual factors, specific and quantitative, may be postulated as affecting the pain mechanisms just outlined. Studies of other pain mechanisms lend support to the dual concept.[1, 19]

Before closing the discussion mention should be made of the fact that in Case 2 sensory stimuli originating in dermatomes adjacent to the amputation site, induced dysesthesia in the phantom limb. Similar phenomena have been observed after other types of injury to the nervous system,[17] and are in keeping with laboratory experiments[10] showing that a sensory stimulus applied to the spinal cord is reflected at all levels in a degree that diminishes with distance.

The transitory postoperative hypalgesia in conjunction with hyperthermesthesia encountered in all the above patients is probably similar in nature to the paradoxical hyperalgesia in the presence of subnormal cutaneous sensation which occurs after certain incomplete peripheral nerve injuries or during recovery from nerve block. The same phenomenon has been described by Browder[2] following posterior cordotomy for relief of phantom limb pain in the lower extremity. This effect is probably due to physiologic disturbances of sensory relays within the affected segments of the spinal cord.

## CONCLUSIONS

1. Relief of phantom limb pain may be achieved by posterior cordotomy alone, and by posterior cordotomy plus sympathectomy.

2. Phantom limb *pain* may be of two kinds, which may occur concurrently: (a) Burning pain, presumably of autonomic origin; and (b) cramped-posture pain, due in part to disturbance of proprioceptive circuits, which can be relieved by posterior cordotomy.

3. The imagined *posture* of a phantom limb appears to be due primarily to dysfunction of suprasegmental (thalamocortical) rather than segmental (spinal) circuits.

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# STREPTOMYCIN IN SURGICAL INFECTIONS
# II. INFECTIONS OF THE GENITO-URINARY TRACT

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A STUDY of the therapeutic value of streptomycin in surgical infections was begun in the Halloran General Hospital in July, 1945. The types of cases studied include battle wound infections, peritonitis, bacteriemias, infections of the respiratory tract, and infections of the genito-urinary tract. The laboratory aspects of this investigation have been reported in detail elsewhere.[1] This paper is a report on the experiences in the treatment of genito-urinary infections with streptomycin.

1. *Pharmacology:* Streptomycin hydrochloride (Merck) or the sulfate (Abbott, Pfizer, Squibb, and others) is dispensed as a fine yellow-orange crystalline powder, in ampoules containing 0.5 gram or one gram. It is standardized so that one gram contains 1,000,000 "S" units, each unit being equivalent to one microgram. Because of the size of unit, and of possible confusion with the unrelated penicillin unit, it is preferable to express streptomycin values in terms of weight. Hereafter, in this report, dosages will be given in terms of grams, and bacterial sensitivities and body fluid drug levels in terms of micrograms. For parenteral administration, the contents of an ampoule are dissolved by adding sufficient sterile isotonic saline to make a ten per cent solution, for example, ten cc. to the one-gram ampoule.

It has been amply demonstrated[2] that streptomycin reaches the blood stream shortly after intramuscular administration, and that it is excreted rapidly by the kidneys. The rate of excretion is slower than that of penicillin, allowing the drug to be given at less frequent intervals. The intramuscular method of administration is preferred to intravenous injection, which has no advantage, and which is attended by the danger of occasional acute toxic reactions. If the drug is given orally, very little of the streptomycin diffuses into the blood stream, and little or none of it appears in the urine. For this reason, oral administration is worthless in genito-urinary infections, and is limited to those diseases in which a high intra-enteric concentration is desirable.

2. *Dosage:* The first group of patients selected for streptomycin therapy in this hospital were those with spinal cord injuries. These patients are notoriously subject to various urinary tract infections and their sequelae, and they have been treated heretofore with penicillin, sulfonamides and other urinary tract antiseptics with variable success. Seven patients with polybacterial infections were treated with 0.2 gram (200,000 "S" units) of streptomycin intramuscularly every four hours, for a total of 18 doses, or 3.6 grams each. In two cases the results were considered good, while in the five others, the organisms reappeared and the pyuria recurred after a temporary slight improvement. To five other patients 0.15 grams was then given every three hours for 24 doses, for the same total dosage of 3.6 grams each. The results

were the same as in the first group of patients. The organisms became streptomycin-resistant. By this time it became apparent that larger doses of streptomycin would be required, and that even then, the outcome of treatment would be dependent to some degree on complicating factors present in addition to the infections. Another group of four patients each received 0.375 grams of streptomycin, administered every three hours for 24 doses, or a total of nine grams. The results were better. In each instance the urine cleared in the second day of treatment, and remained so. The *nonhemolytic Streptococcus* was found on culture of some of the urines after treatment, but its presence was not associated with clinical evidence of infection. All other organisms disappeared. A more detailed report of these earlier experiences with streptomycin treatment of urinary tract infections in patients with spinal cord injuries will be published by Kleinman and Shearer.[3]

With data from these cases as a background, the author undertook detailed study of a series of patients with genito-urinary tract infections, to determine the exact limitations and indications for streptomycin. On the basis of experience obtained with a large series of battle wound infections, the dosage scheme of 0.4 grams of streptomycin dissolved in four cc. sterile isotonic saline, administered intramuscularly every four hours, was adopted. It was found advisable to mix one cc. of one per cent procaine with the four cc. of streptomycin solution, to alleviate the pain which occurs following injection. Typical streptomycin assays of blood serum and urine with this dosage are listed in Table I. The levels shown in the table are sufficient to sterilize the

TABLE I

CONCENTRATIONS OF STREPTOMYCIN IN BLOOD AND URINE

| Case No. | Blood Serum Assay | Urine Assay |
|---|---|---|
| 22* | 8–16 U./cc. | 73– 153 U./cc. |
| 27 | 4–16 | 2000+ |
| 28* | 16–32 | 64– 256 |
| 29* | 32–32 | 128– 256 |
| 40 | 4–32 | 2000–2000+ |
| 41 | 4–32 | 1000–4000 |
| 42 | 8–16 | 500–2000 |
| 45 | 8–32 | 500–4000 |
| 53 | 8 | 500–2000 |
| 54 | 8–16 | 500–2000+ |
| 59 | 4–16 | 500–2000 |
| 66 | 8–16 | 512–1000 |
| 69 | 8– 8 | 128–1024 |
| 70 | 4–16 | 128–1024 |
| 72 | 4– 8 | 128–1024 |
| 74 | 4–16 | 1024–2048 |
| 76 | 4–16 | 1024–4096 |

* Marked impairment of renal function.

urines, provided the bacteria are not naturally resistant, that resistance has not been produced by previous underdosage, that renal function is adequate, and that there are no unsterilizable foci, caused by calculi or undrained abscesses. Streptomycin in concentrations above 1000 U./cc. reduces alkaline copper (Benedict's reagent) solutions. This reaction can be used as a rough

guide to determine the urine streptomycin level when facilities are not available for the more complicated exact assay of the drug.

3. *Bacteriology:* Routinely, urine specimens are cultured prior to treatment, and are repeated daily during therapy, then once weekly thereafter for two or more weeks. In males, specimens are obtained by voiding into sterile containers, but in indicated cases, urethral or ureteral catheterization is performed. All specimens are cultured aerobically and anaerobically. Each bac-

TABLE II

SUSCEPTIBILITY TO STREPTOMYCIN OF BACTERIA FROM 63 URINARY TRACT INFECTIONS

| | Total No. of Strains | Number of Strains Inhibited by Streptomycin | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Micrograms per cc. | 0.5 U./cc. | 1.0 U. | 2.0 U. | 4.0 U. | 8 U. | 16 U. | 32 U. | 64 U. | 128 U. |
| *Strep., nonhem.* | 46 | 7 | | 2 | 12 | 6 | 14 | 4 | | 1* |
| *P. vulgaris* | 40 | | | 5 | 8 | 7 | 15 | 2 | 3 | |
| *A. aerogenes* | 29 | | 2 | 5 | 6 | 5 | 4 | 2 | 3 | 2[b] |
| *E. coli* | 22 | | 1 | 5 | 3 | 8 | 3 | 2 | | |
| *Staph. aureus* | 22 | 10 | 3 | | 3 | 1 | | | | 5[c] |
| *K. pneumoniae* | 14 | | 1 | 4 | 1 | 3 | 3 | | 1 | 1[d] |
| *Ps. aeruginosa* | 14 | | | | | 3 | 7 | 1 | | 3[d] |
| *Strep., hem.* | 7 | | | | 3 | 3 | | | | 1[b] |
| *Strep. viridans* | 7 | | | | 1 | 1 | 2 | | | 3[d] |
| Totals | 201 | 17 | 7 | 21 | 37 | 37 | 48 | 11 | 7 | 16[b] |

[a] Streptomycin-resistant.

terial species is isolated in pure culture and tested for streptomycin sensitivity.

Table II summarizes the 201 aerobic bacterial flora grown from the urines of 63 patients, and their sensitivity in broth to streptomycin. It is evident from this table, that most of the infections encountered are polybacterial in character. *Streptococcus nonhemolyticus (fecalis)* and the gram-negative bacteria are the predominating etiologic organisms in genito-urinary infections. The great majority of bacteria listed are sensitive *in vitro* to 16 (or less) U. per cc. Sixteen strains of a total of 201 (eight per cent) were found to be naturally resistant, and ten of these are gram-positive cocci. The susceptibility to streptomycin of the gram-negative bacilli and of the *nonhemolytic Streptococci* is of utmost clinical importance, in view of the fact that these organisms usually are indifferent to the action of penicillin and the sulfonamides.

4. *Clinical Investigation:* A special ward, adjacent to the Urologic Ward, has been set up, where complete and independent control of patients receiving streptomycin is effected. In addition to routine work-up before starting treatment, the following laboratory studies are made: complete blood count, sedimentation rate, hematocrit, blood urea nitrogen, urinalysis, and the already mentioned identification of the etiologic organisms and determination of their susceptibility to streptomycin. Urinalyses are repeated daily during treatment and once or twice weekly thereafter for two weeks. Intake and output measurements of fluid are maintained during the period of drug administration.

Streptomycin blood serum levels are made daily on blood which is drawn just prior to a scheduled injection, while urine assays are determined on 24-hour collections of urine. In addition, any other preliminary studies are accomplished which will give information on the results of therapy on the infection. Blood pressures are taken every two hours for 12 hours with every new batch of drug. Concomitant malnutrition, anemia, general debility and other factors are evaluated and treated as encountered (all data derived from study of these cases are assembled on standard streptomycin form sheets).

TABLE III

INFECTION IN THE URINARY TRACT IN PATIENTS WITH SPINAL CORD INJURIES

*Dosage Scheme: 0.4 Gram Intramuscularly Every 4 Hours*

| Case No. | Diagnosis | Bacteriology and Strep.-sens. | Days Treated | Result |
|---|---|---|---|---|
| 1 | Recurrent pyelocystitis with acute episode | *A. aerog.*, 2 U.<br>*E. coli*, 4 U.<br>*Hem. Strep.*, 8 U. | 3 | Good. Urine sterilized, temperature subsided |
| 22 | Pyelocystitis, pyonephrosis with renal calculi, left, uremia | *A. aerog.*, 2 U.<br>*E. coli*, 8 U.<br>*B. proteus*, 8 U.<br>*Nonhem. Strep.*, 8 U. | 5 | Failure. Poor renal function resulted in low urine drug concentration. Calculi are nonsterilizable. Bacteria became drug-fast |
| 40 | Severe chronic cystitis, persistent suprapubic fistula with suppuration | *A. aerog.*, >128 U<br>*K. pneu.*, >128 U.<br>*Staph. aureus*, 8 U.<br>*Anaerobic cocci* | 6 | Failure. Temporary reduction in bacterial colony count and pus cells in urine, followed by prompt recurrence of severe pyuria |
| 42 | Recurrent pyelocystitis with persistent suprapubic fistula | *A. aerog.*, > 128 U.<br>*Nonhem. Strep.*, >128 U.<br>*Viridans Strep.*, >128 U. | 5 | Failure. Organisms insensitive. No improvement resulted from subsequent continuous infusion of streptomycin into the bladder *via* Foley catheter |
| 59 | Chronic pyelocystitis | *A. aerog.*, 2 U.<br>Anaerobic coccus<br>Anaerobic Strep. | 3 | Good. Cultures negative after 3 days treatment. No recurrence |
| 76 | Chronic cystitis | *Staph. aureus*, 64 U.<br>*Viridans Strep.*, 32 U. | 6 5 | Good. Urine cleared though *Staph. aureus* persisted. Combined penicillin and streptomycin sterilized the urine |
| 24 | Recurrent pyelonephritis, bladder calculi, and right vesico-ureteral reflux. (Had previous streptomycin therapy.) | *Ps. aerog.*, 128 U.<br>*B. proteus*, >128 U.<br>*Nonhem. Strep.*, >128 U.<br>*Staph. aureus*, 0.5 U. | 3 | Failure. Previous drug administration made organisms insusceptible |
| 69 | Recurrent pyelonephritis, chronic urethritis and prostatitis. (Had previous streptomycin therapy.) | *Staph. aureus*, >128 U.<br>*Hem. Strep.*, 64 U.<br>*B. proteus*, >128 U. | 3 | Doubtful. *Hem. strep.* disappeared. Urethral discharge ceased, bladder capacity increased, automaticity improved |

5. *Evaluation of Results:* (a) Table III summarizes the outcome of urinary tract infections in eight paraplegics treated with streptomycin. All of these patients had varying degrees of neurogenic bladders, and have had suprapubic cystostomies performed overseas, arriving at this hospital with severe urinary tract infections. All had received penicillin and sulfonamides without result. In three instances the streptomycin effected a prompt, dramatic and lasting sterilization of the urine. Each of these three had no suprapubic fistula, no residual urine, and excellent renal function. The organisms

were highly susceptible to streptomycin in each case. Among the five failures, one patient (Case 22) had uremia due to obstruction of one kidney by calculi and of the other by pyonephrosis. In retrospect, it would have been advisable to have waited for improvement in renal function, which followed bilateral ureteral catheter drainage. The other four failures, on reconsideration, should not have been given streptomycin. Two cases (Cases 40 and 42) had naturally resistant organisms, and, therefore, therapy was futile. They emphasize the importance of delaying treatment until bacterial sensitivities are known. The last two failures in this series were in-patients who had previous streptomycin therapy, and emphasizes the importance of the fact that underdosage rapidly produces permanent drug resistance, since resistant bacteria propagate resistant bacteria.

(b) Table IV shows the results of treatment of 13 patients with non-venereal genito-urinary tract infections. In seven patients with cystitis and pyelonephritis, the urine cleared within 24 to 48 hours, and remained sterile thereafter. One of these patients (Case 41) had an associated epididymitis which subsided rapidly. In another (Case 34) streptomycin was continued for nine days while treating an associated chronic osteomyelitis of the ilium, which improved in conjunction with sequestrectomy. The remaining five of the seven patients received only three days of treatment (7.2 grams or 7,200,000 units). Of the six failures, Case 28 improved clinically, but the *Ps. aeruginosa,* originally sensitive to four U./cc., became resistant to over 2,000 U./cc. This patient had an atonic ureter, a dilated pelvis with retention, and an indwelling pyelostomy tube, and illustrates the importance of obtaining good drainage and removing tubes. Case 29 (Chart 1) was treated for seven days, during which he was critically ill with a bacteriemia, secondary to a right pyonephrosis for which indwelling ureteral catheter drainage was instituted. Renal function was poor bilaterally, and resulted in very high blood levels of the drug and very low urine levels. The bacteriemia subsided, repeated blood cultures becoming negative, but his urinary tract infection did not clear-up. The offending organism, *A. aerogenes,* originally susceptible to 4 U./cc. streptomycin, became resistant to over 2,000 U./cc. Cases 53 and 66 are considered failures, even though the patients remain improved clinically. The gram-negative bacteria disappeared during treatment but the gram-positive cocci, naturally resistant in these two cases, remained after treatment. Both of these cases had small, silent calculi in the calices, for which surgery was not indicated at the time. It remains to be proved whether complete sterilization of the urine can be achieved in the presence of calculi when the infection is due to susceptible bacteria. Case 45 was a severe chronic prostatitis with a chronic gleet, whose prostatic secretion was almost pure pus. Although the urethral discharge stopped and the urine cleared, the prostatic fluid remained purulent. It is of interest that no streptomycin could be assayed in the prostatic fluid. It is possible that more beneficial results might be forthcoming, in such a case, if better prostatic drainage is established during systemic streptomycin therapy by repeated prostatic massage. Case 70 continues to show the resis-

tant *Strep. viridans* in the urine, but is clinically improved. This patient had a chronic interstitial cystitis and a contracted bladder. The bladder capacity was 30 cc. before treatment, and he had to urinate every 10 to 15 minutes. Following treatment the capacity of the bladder went up to 90 cc. with diminution of frequency and spasm. He is showing progressive improvement without further chemotherapy.

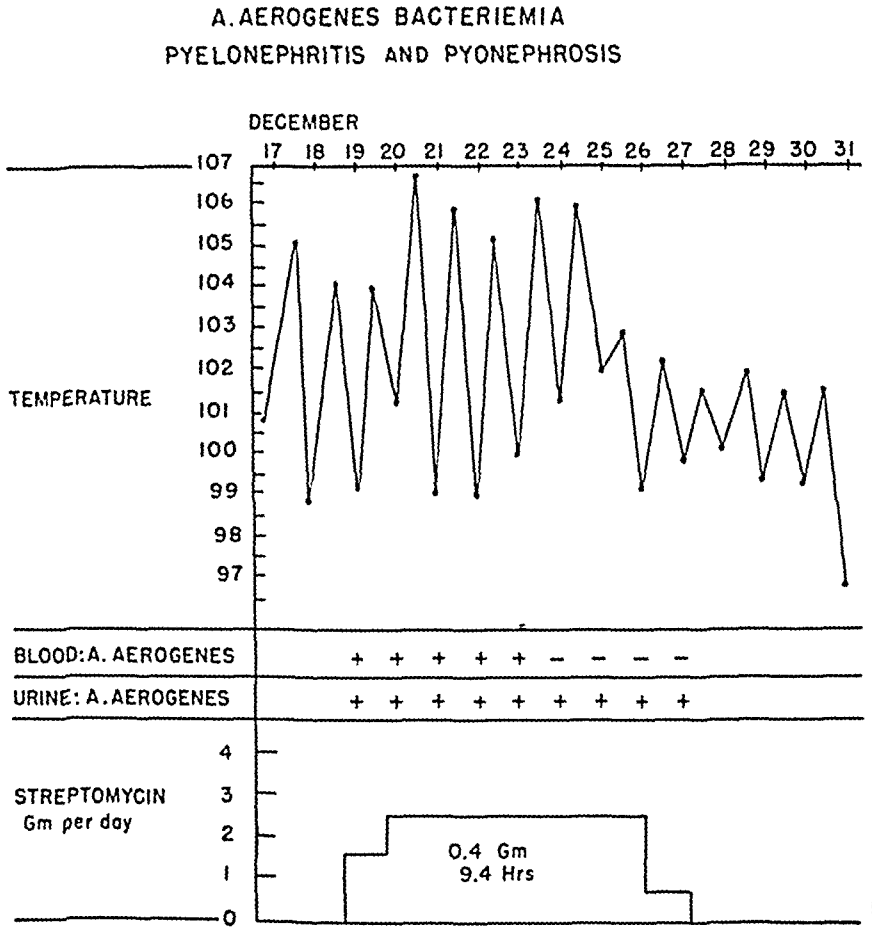



CHART I.

(c) In Table V are presented two cases in which streptomycin was instilled into the urinary tract directly. Both are considered failures from the bacteriologic standpoint, although there was clinical improvement. Case 14, an infected hydroureter due to stricture, received intra-ureteral instillations of 150,000 U. of streptomycin in 15 cc. of isotonic saline (10,000 U./cc.) every two hours for 48 hours. The gross pyuria subsided and the urine remains clear, but the cultures remain positive for *B. proteus*. Case 19, in whom a stag-horn calculus dropped from the kidney pelvis and caused obstruction at the middle third of the ureter, was operated upon, but, following extraction of the calculus from the ureter, there was a gush of thick pus. A catheter was inserted up to the kidney pelvis through the ureterotomy. Postoperatively, 10 cc. of streptomycin solution, 5,000 U./cc., was instilled, through the catheter twice daily, for 20 days. The urinary drainage became clear, but did not be-

come sterile. The wound healed rapidly following removal of the catheter. The patient had one large calculus in the bladder (3 cm. in diameter) and several smaller calculi. Since removal of these by litholapaxy, the patient's urinary tract infection has subsided.

TABLE IV

INFECTIONS IN THE URINARY TRACT: 13 CASES

*Dosage Scheme. 0.4 Gram Streptomycin Intramuscularly Every 4 Hours*

| Case No. | Diagnosis | Bacteriology and Strep.-sens. | Days Treated | Result |
|---|---|---|---|---|
| 10 | Recurrent cystitis, posterior urethritis | *E. coli*, 4 U. | 3 | Good. Urine cleared in first 24 hours of treatment—has remained so |
| 27 | Chronic pyelonephritis associated with recurrent calculi requiring ureterolithotomy | *E. coli*, 2 U.<br>*Staph. aureus*, 0.5 U.<br>*Nonhem. Strep.*, — | | Good. Urine became sterile. No recurrence |
| 28 | Hydropyonephrosis. Post-pyeloplasty, ureterolysis and pyelostomy | *Ps. aerug.*, 4 U.<br>*Viridans Strep.*, 16 U.<br>*Staph. aureus*, 0.5 U. | 3 | Doubtful. Temperature subsided with change from Penicillin to streptomycin but *Ps. aeruginosa* persisted, became drug fast |
| 29 | Pyelonephritis, pyonephrosis, bacteriemia | *A. aerog.*, 4 U. | 7 | Doubtful. Blood stream cleared but urine did not. Poor renal function, low drug levels in urine, high levels in blood. Organisms in urine became resistant |
| 34 | Cystitis, fractured pelvis, with osteomyelitis | *E. coli*, 8 U.<br>*B. proteus*, 8 U.<br>*Strep. viridans*, 8 U. | 9 | Good. Cystitis cleared in 2 days of treatment. Additional therapy was for osteomyelitis |
| 41 | Cystitis and epididymitis | *K. pneu.*, 2 U.<br>*Staph. aureus*, 4 U.<br>Diphtheroid bacilli, 2 U. | 4.5 | Good. Urine cleared after 24 hours, inflammatory reaction in the epididymis resolved. No recurrence |
| 54 | Chronic pyelonephritis | *A. aerog.*, 4 U.<br>*Anaerobic nonhem. Strep.*, — | 3.5 | Good. Urine cleared in 24 hours and has remained so |
| 72 | Chronic cystitis | *A. aerog.*, 4 U.<br>*E. coli*, 8 U.<br>*Staph. aureus*, 0.5 U. | 3 | Good. Urine sterilized and has remained crystal clear |
| 74 | Chronic pyelonephritis | *B. proteus*, 2 U.<br>*Staph. aureus*, 1 U.<br>*Nonhem. Strep.*, 2 U. | 3 | Good. Prompt response with sterilization of urine without recurrence |
| 53 | Chronic pyelonephritis with small silent renal calculi | *B. proteus*, 8 U.<br>*P. morganii*, 8 U.<br>*Ps. aerug.*, 8 U.<br>*Hem. Staph. aureus*, >128 U. | 5 | Fair. Urine cleared. Pus cells became rare, but *Staph. aureus* remains |
| 66 | Pyelonephritis with small silent left renal calculi | *A. aerog.*, 8 U.<br>*E. coli*, 16 U.<br>*Hem. Staph. aureus*, 128 U.<br>*Hem. Strep.—beta*, 128 U. | 6 | Doubtful. Resistant gram-positive cocci disappeared after combined streptomycin and penicillin only to reappear after cessation of treatment |
| 45 | Chronic prostatitis and cystitis | *A. aerog.*, 4 U.<br>Micrococci, 0.5 U.<br>Diphtheroid bacilli, 0.5 U. | 6 | Doubtful. Morning drop ceased and urine cleared partially. The foci in the prostate remained. No measurable streptomycin level in prostatic fluid |
| 70 | Chronic interstitial cystitis and prostatitis, contracted bladder | *Staph. aureus*, 4 U.<br>*Viridans Strep.*, >128 U. | 5 | Failure. *Strep. viridans* unaffected |

## DISCUSSION AND SUMMARY

During the past nine months the use of streptomycin in a variety of urinary tract infections has revealed indications and contraindications for the use of this antibiotic. The exact limits for usage of this drug is still under investigation. The drug shows its most important action against the gram-negative organisms including *E. coli, P. vulgaris, A. aerogenes, K. pneumoniae, Ps. aeruginosa,* and others. Not all of the species in each of these groups are sus-

TABLE V

GENITO-URINARY INFECTIONS TREATED WITH LOCAL STREPTOMYCIN

| Case No. | Diagnosis | Bacteriology and Streptomycin Sensitivity | Scheme of Treatment | Condition at End of Streptomycin Course | Final Result |
|---|---|---|---|---|---|
| 14 | Congenital hydroureter, infected, with stricture at ureterovesical junction | *B. proteus*, 8 U. *Hem. Staph. aureus*, 128 U., *Hem. Strep.*, 8 U. | 15 cc., Strep. sol., 10,000 U./cc. injected into ureteral catheters q.2.h. for 48 hrs. (1.7 Gm.) | Urine changed from cloudy to crystal clear but bacteria persisted as before treatment, became resistant | Urine continues to harbor *B. proteus*, but the specimens remain clear |
| 19 | Stag-horn calculus in midureter, rt., removed. Wound infection | *Hem. Strep.*,— *B. proteus*, 4 U. *A. aerog.*, 64 U. | 10 cc., 5,000 U./cc. sol. instilled into wound twice daily for 10 days (1.0 Gm.) | The wound infection subsided, wound closed, urine became clear but not bacteria free | Persistence of bladder infection due to calculi in bladder. Infection cleared after litholapaxy |

ceptible to streptomycin. Of additional significance is the potency of the drug against the gram-positive cocci, particularly the *nonhemolytic Streptococcus.* It has been possible to sterilize infections of all portions of the genito-urinary tract, except the prostate, due to these organisms.

It has been shown that streptomycin action is greater in alkaline media[4] and alkalinization of the urine has been performed in several cases, prior to institution of streptomycin therapy. However, in case urea-splitting organisms, *(B. proteus)* are present, the advantages of alkalinizing the urine are offset by the increased rapidity of bacterial growth, plus the fact that in alkaline media there is greater tendency to precipitation of calcium phosphate. This combination of complicating factors is of importance in our paraplegias and orthopedic cases where the tendency to form calculi of recumbency is so great. This tendency toward calculus formation is also of importance and must be watched when we restrict the fluid intake in order to increase the urinary streptomycin level. Our data indicates that urinary streptomycin levels from 500 micrograms (U.) per cc. to 2,000 micrograms (U.) per cc. can be achieved by restricting the fluid intake to 2,500 cc. per day and administering streptomycin in doses of 0.4 gram intramuscularly every four hours. These levels are sufficient to sterilize most urines when the bacteria are susceptible and when there are no complicating factors.

Preferably, paraplegics should be treated only after they have automatic bladders and closed cystostomy wounds. The skin of these patients is notorious for harboring fecal organisms which are not eradicated by routine

hygienic measures. If catheterizations are needed during or following treatment, drug-resistant reinfection may result. In this group of patients, with spinal cord injuries, where such contraindications are present, streptomycin therapy should be reserved only for those who have uncontrolled, severe, upper tract infections or actual septicemia.

In view of the fact that only sensitive species of organisms in the group of gram-negative bacteria and gram-positive cocci respond to streptomycin, provided dosage is adequate, and because irreversible resistance of bacteria follows inadequate doses of drug, the cases selected for treatment must be rigidly controlled, lest the future value of streptomycin be destroyed for that particular patient.

The drug should not be used in instances of infection associated with uncompleted surgery, such as the presence of operable calculi. However, the drug may be given immediately before operation and during the patient's postoperative course. The drug should not be given where repeated catheterization or instrumentation which may reintroduce infection is required. Where there is a residual urine or where the patient has indwelling urethral catheters or pyelostomy or nephrostomy tubes, streptomycin should be delayed until these drainage tubes are removed. The drug is ineffective in instances of suppuration where surgical drainage has not been instituted.

In the present of small calculi in the calices for which surgical treatment is not indicated, further investigation is necessary to determine if a sterile urine can be achieved following the use of intensive treatment.

For local treatment, streptomycin has been used in saline solutions. Local application has the advantage of securing immediate high concentrations within the area of instillation, and, at the same time, permits considerable economy in the use of the drug. Irrigation of the kidney pelvis has been performed with solutions of streptomycin containing 5,000 and 10,000 micrograms (U.) per cubic centimeter. However, the mode of treatment must be individualized for each case. There is no convincing evidence to date of any advantage in urinary tract infections of local treatment alone over systemic streptomycin therapy.

The effectiveness of the drug in genito-urinary tuberculosis has not been evaluated. Being an hemotogenous infection, widespread throughout the body and manifested by an open lesion in one or both kidneys, systemic therapy and tremendous doses over a long period of time will be necessary and these cases will require considerable study. For the present, it is felt that the treatment of unilateral ulcerocavernous type of renal tuberculosis is still surgical. The effectiveness of local application of the drug for postnephrectomy tuberculous sinus tracts also requires further study.

In instances where a mixed urinary tract infection of gram-positive and gram-negative organisms exists, combined therapy using both streptomycin and penicillin has been found to be of value. There is no contraindication to combining the two antibiotics.

It is emphasized that in the usual case of infection in the genito-urinary

tract, three days of systemic streptomycin therapy, with the dosage recommended, is adequate. No advantage has been demonstrated with more prolonged treatment. It has not been found necessary to keep patients in bed during administration of streptomycin, if the patient's condition permits him to be up and about. There have been no serious drug reactions with these short courses of therapy. Pain at the sites of injection is usual. It is advisable to rotate the injections between the deltoids and gluteal muscles. Fall in blood pressure, asymtomatic except for mild headache and dizziness, has been noted following administration of some batches of the drug. In one case a diffuse morbilliform rash occurred which disappeared on withdrawal of the drug. Traces of "sugar" in the urine may be reported while the patient is undergoing streptomycin therapy. It is reiterated that this phenomenon is due, in part, to the reducing action of high concentrations of streptomycin on alkaline copper solutions. Blood sugar determinations on these patients are normal.

## CONCLUSIONS

1. Forty cases of urinary tract infections treated with streptomycin at the Halloran General Hospital indicate that this antibiotic is a potent addition to the armamentarium of the urologist, particularly against the gram-negative bacteria, and the gram-positive cocci.

2. Cases selected for this treatment should be rigidly controlled for bacterial susceptibility, adequate renal function, and absence of urinary tract obstruction or calculi. Successful therapy depends on a free flow of urine, susceptible bacteria and adequate dosage.

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# ANTRAL GASTRITIS AND SPASM: THEIR CLINICAL AND SURGICAL SIGNIFICANCE

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DURING THE PAST TEN YEARS on the North American continent with the use of the "spot-film device" for the study of the mucosal patterns of the stomach by radiography, and with the extended use of the flexible gastroscope, due to the efforts of Schindler, the diagnosis of gastritis has become a problem to the radiologist and the surgeon especially in those cases where there is ulceration or hypertrophic processes which may simulate neoplasm of the stomach. Apart from a type of hypertrophic gastritis which produces giant rugae on the greater curvature of the stomach, and which may be mistaken for a neoplastic defect,[3, 7] the most difficulty to the surgeon from a clinical and surgical point of view is caused by the variety labelled "antral gastritis"[5] or "hypertrophic antrum gastritis."[1] Although spasm or inflammation may involve any part of the stomach, they are more commonly observed in the antrum. As this part of the stomach is a common site of carcinoma, antral gastritis and spasm are of particular importance to the surgeon because of the difficulties that arise in differential diagnosis. The internist on the other hand is mainly interested in those cases which fit mainly into the classification of gastritis developed by Schindler who differentiates: (1) Superficial gastritis; (2) atrophic gastritis; (3) hypertrophic gastritis; and (4) gastritis of the postoperative stomach. This classification does not greatly assist the radiologist who is able usually to distinguish only the hypertrophic type, and referring as it does to the mucosal lesions as seen by the gastroscopist it does not distinguish the variety of inflammatory lesions that are seen in the antrum. There is also serious doubt that the first type, superficial gastritis, is always clearly distinguishable, as the reddening and congestion described in this type are known to occur normally during periods of emotion such as anger. Nevertheless, it is generally agreed that the gastroscopist, particularly in the body of the stomach, can more easily and with more certainty make a diagnosis of gastritis than the radiologist.

Because it is the radiologist who, after perhaps a test meal, makes the initial examination of the stomach of a patient with gastric complaints, a great deal of responsibility devolves on him to correctly assess the amount of spasm in the antrum or any disturbance of antral systole[5] which he may see during the fluoroscopic examination, because it is his judgment of this spasm which determines largely the diagnosis of antral spasm. If the spasm is marked or persistent then the radiographs may show this persistent spasm in serial films as an elongation and narrowing of the antrum, giving a picture that is very similar to that of some cases of antral gastritis. Also during fluoroscopic examination, and assisted by radiographic studies of the mucosal pattern of the antrum, he must estimate any rigidity or abnormality of the normal mucosal folds before

making a diagnosis of antral gastritis. In our experience, a diagnosis of localized prepyloric hypertrophic gastritis has been made too frequently by radiologists in patients showing some degree of antral spasm with radiographic evidence of marked folds when on gastroscopic examination no evidence of any inflammatory process could be seen, and even the folds were obliterated by the distention necessary to the examination. This difficulty was foreseen by Gorsell,[4] in 1923, when he stated that: "Great experience and thorough comparative investigation are necessary before we are able to distinguish the pathologic types of the relief from the normal ones, and to separate the outlines formed by the defects or infiltrations of the intestinal wall from the relief of a contracted mucous membrane." And, more particularly, the fervent hope of



FIG. 1



FIG. 2

FIG. 1.—Case 1: Antral spasm, slight indentation of duodenal cap. Normal folds.
FIG. 2.—Case 1: Normal stomach one year later. Border folds of Chaoul clearly seen.

Kirklin,[8] in 1937, "further I hope that neither the roentgenologic and the gastroscopic diagnosis of gastritis will become common until the morbid anatomy of the disease, its right to be considered a pathologic entity and its clinical significance become better understood and more firmly established," still holds a great deal of truth today. Therefore, it is desirable that the diagnosis of antral gastritis be made only in those cases where there is demonstrable stiffening and irregularity of the antral mucosal folds or presence of an inflammatory filling defect, or where definite signs of inflammation are seen on gastroscopic examination. The degree of corelation between the roentgenologic and gastroscopic diagnosis of gastritis is stated by Renshaw[13] to be 93 per cent. In 842 cases, a positive diagnosis of gastritis was made in 17.7 per cent where there was a negative roentgenologic examination, and in 7.9 per cent of cases disease was excluded where a positive diagnosis of gastritis had been made by the radiologist.

The symptomatology of antral spasm and gastritis, unfortunately, presents no classical pattern such as is usually stated for peptic ulcer, carcinoma of the stomach or gallbladder disease, but is a peculiar combination of the symptoms of all three conditions. Pain in the epigastrium is the outstanding symptom. The pain bears no constant relation to food, being sometimes relieved, but more often made worse by eating. Anorexia with weight loss is common, and distaste for fats and heavy fried foods is common. In antral gastritis, hemorrhage is said to occur in 19.7 per cent of cases (Benedict).[2] In reviewing 34 cases of antral spasm found during 487 consecutive roentgenologic examinations of the stomach, it was found that these cases had an amazing similarity in their



FIG. 3



FIG 4

FIG. 3—Case 2. Hypertrophic antral gastritis. Elongation and narrowing of antrum. Kirklin's sign present. Thickened antral folds.
FIG. 4.—Case 2: Progressive improvement six months later.

symptoms, and it is of further interest that these symptoms do not vary significantly from those cases of antral gastritis which we have seen.

Physical examination yields little information. Schindler has described a tender area to the left of the navel in some cases.[14]

Gastric acidity tends to be normal or high in cases of antral gastritis, but in antral spasm we have found that the free acid is low or absent with an ordinary test meal.

As has been mentioned, antral spasm is best estimated by the radiologist during fluoroscopy and with serial films which show the constant spasm without derangement of the normal folds of the antrum during contraction of the antrum. A detailed discussion of the mechanism of the production of these folds is without the scope of this paper. A roentgenologic diagnosis of antral

gastritis can be made during fluoroscopy in the presence of a deranged antral systole coupled with the finding of stiff unnatural folds which cannot be obliterated by pressure. The radiographs characteristically show persistent spasm with elongation and funnel-shaped narrowing of the antrum. Sometimes there is indentation of the duodenal cap said to be due to the stiffened mucosa being squeezed through the pyloric ring. This sign, "Kirklin's sign," is seen most characteristically in the type of case called pyloric stenosis[11] in adults, and which according to Stout are associated with histologic evidence of gastritis.



FIG. 5.—Case 3: Extreme hypertrophic antral gastritis, simulating carcinoma.

This extrusion of the mucosa through the pyloric ring may also be extreme in gastritis, without hypertrophy of the pylorus, and is recently reported[12] as "extrusion of the mucosa through the pyloric ring." The mucosal pattern, although enlarged and stiffened, is not usually disrupted, and the folds on relief can be seen both fluoroscopically and radiographically to run through the antrum. Even in the extreme hypertrophic forms, the complete normal architecture is not always disturbed, and the border folds of Chaoul can often be identified.

As yet no pathologic classification seems complete to cover all the types of inflammation in the antrum of the stomach seen roentgenologically, at operation, or in the pathology laboratory after gastric resection. Schindler's classification covers those seen gastroscopically and refers mainly to the changes in the mucosae as does the classification given by Vaughn,[15] in which he divides the gross pathology into three types—(1) acute edematous; (2) ulcerative;

and (3) chronic inflammatory, with hypertrophy, which he correlates with the gastroscopic pictures of—(a) reddening with edema; (b) reddening with ulceration, and chronic hypertrophic gastritis or the cobble stone appearance. Neither Schindler's or Vaughn's classification appear to include a type of hypertrophic antral gastritis of which the three cases described by Konjetzny[10] are similar to Case 3 presented in this paper. Also, the above classification seems to indicate that the process begins in the mucosa and submucosa and may spread to the deeper tissues. Particularly in the extreme hypertrophic forms it may be that the process is an interstitial gastritis, and the mucosal changes and the ulceration may be secondary.

Unexplained, also, is the relation of spasm which is always present. If an analogy holds to the rest of the gastro-intestinal tract, it may be that a disturbance in function exhibited as spasm is the underlying factor, and that the mucosal, and submucosal or interstitial inflammation or hypertrophic changes, are secondary to the spasm.

The differential diagnosis is of interest to the surgeon mainly in those cases with a defect in the antrum which simulates carcinoma. Attention to mucosa relief patterns will provide the diagnosis in many cases aided by gastroscopic examination. However, there are some cases[6] in which a definite differential diagnosis cannot be made between inflammatory infiltration of the antrum, ulceration, hypertrophic defects, and carcinoma. These doubtful cases may be observed for short periods, and with repeated examinations, but if after this brief period of observation a definite diagnosis cannot be made, then exploration should be carried out. It should be emphasized that even at operation it still may not be possible to rule out carcinoma, and even biopsy is not infallible. If any doubt as to exact nature of a lesion in the antrum exists at celiotomy, gastric resection should be done without further delay. With the present reasonably low mortality for gastric resection, delay in operation, with its risk of permitting an operable carcinoma to develop into an inoperable one, is unjustified.

## CASE REPORTS

**Case 1.**—P. D., a 47-year-old white male, with stomach trouble for one year. Attacks of epigastric distress present for one month. Pain comes on four hours after eating. Gas on stomach troublesome. Loss of 14 lbs. weight in one year. No free acid (19 units in one hour). Roentgenologic examination: Localized prepyloric gastritis. Gastroscopic examination: Mucosa of antrum normal orange-red color. Some folds in antrum but these neither stiffened or nodular. *Diagnosis:* Antral spasm. Patient put on a bland diet and antispasmodics. One year later roentgenologic examination—normal stomach and antrum.

This is a case in which the correct diagnosis is antral spasm.

**Case 2.**—A. C., a 54-year-old white male, with gaseous dyspepsia for one year. Gas causes dyspnea. Distress after meals but no relation to any particular food. Acid—fasting 55/92; one hour 52/84. Roentgenologic examinations: First films showed a defect in prepyloric region which suggested carcinoma. Examination repeated in two weeks after treatment showed improvement, so further observation decided. After six

months defect had disappeared, and only spasm with thickened antral folds present. Symptoms relieved. Patient has remained well. *Diagnosis:* Antral gastritis.

This is a case of antral gastritis in which progressive improvement took place under observation.

**Case 3.**—T. M., a 46-year-old white male. Epigastric discomfort after meals, vomiting occasionally for one year. Anorexia and weight loss 15 lbs. one year. Severe pain on day of admission, with blood in stools. Low acid with test meal. Clinical impression: Ulcer or gastritis. Roentgenologic examination: Annular filling defect in antrum practically occluding pylorus, with appearance of new growth. Operative Findings: Large firm mass in antrum of stomach. Serosa white and infiltrated with small excrescences resembling peritoneal implants. Subpyloric and lower nodes along lesser curvature enlarged. Gross appearance resembled carcinoma, so gastric resection

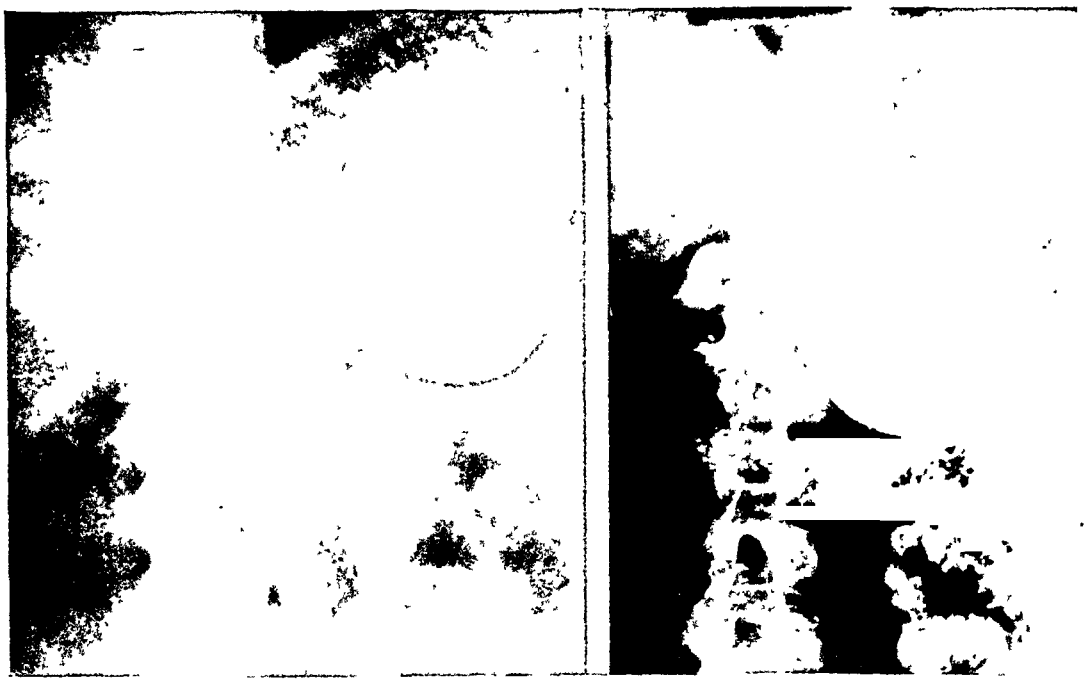


FIG. 6 FIG. 7

FIG. 6.—Case 4: Carcinoma of the pylorus simulating antral gastritis. Gastrostomy negative.

FIG. 7.—Case 4: Carcinoma of the pylorus six months later. Frozen-section negative. Paraffin section—adenocarcinoma of pylorus.

proceeded with on this basis. Anterior Pólya resection, antecolic anastomosis. Uneventful recovery.

*Pathologic Report:* Resected stomach. Large mass in antrum. Stomach opened shows an ulcer, ¾ inches in diameter on anterior wall near lesser curvature, three inches from pylorus. Ulcer is shallow with a necrotic base. Mucosa of antrum is red and edematous and thrown into large folds. The wall of the antrum is thickened, measuring 2 cm. The muscular coat is not interrupted and can be traced through the mass.

*Microscopically:* All coats show edema, with infiltration by large and small lymphocytes, plasma cells and many eosinophils. The reaction is most severe in the submucosa. There is also a diffuse fibrosis throughout the muscular layers.

This is a case of extreme hypertrophic gastritis, which by roentgenologic examination and at operation could not be distinguished from carcinoma.

Treated by gastric resection, with uneventful recovery and relief of symptoms six months after operation.

**Case 4.**—A. R., a 57-year-old white female. Epigastric distress of one year's duration with anorexia. Distress made worse by food. Vomiting recently. No weight loss. No free acid, but moderate amounts of free and combined acid on serial samples with ordinary test meal. Roentgenologic examination: localized prepyloric gastritis with spasm, with 25% retention in five hours. This did not improve on a short medical regimem.

*Operative Findings:* At the pyloric end of the stomach, and invaginating the duodenum was a rubbery induration and thickening of the antrum of the stomach. No discrete mass. Gastrotomy performed. Mucosa normal. Pylorus normal. Impression—antral gastritis. Abdomen closed.

Patient made an uneventful recovery and was well for six months, when vomiting recurred, accompanied by a small loss of weight. No anemia. Roentgenologic examination now showed prepyloric spasm with some narrowing of the pylorus. Peristalsis seen to pass through the antrum to the pylorus.

*Gastroscopic Examination:* Persistent spasm in the antrum. Mucosa of angulus and body of stomach normal. Pylorus not seen due to spasm.

*Operative Findings:* Grossly, the stomach was essentially the same as before. Gastrotomy was performed. Mucosa again appeared normal in the antrum. No ulceration. The pylorus was now narrowed and almost occluded by a ring of firm tissue. Biopsy of the pyloric ring was taken in two places. Frozen-section reported as "chronic inflammatory reaction." Because it was felt that with an apparently normal stomach with a high grade pyloric obstruction that a posterior gastro-enterostomy would be adequate to relieve her symptoms, this was done. Report on paraffin sections: Infiltrating adenocarcinoma of the pylorus. Patient made an uneventful recovery.

This is probably an early case of linitis plastica which on two occasions at operation, even with biopsy, was mistaken for antral gastritis. Resection is now contemplated due to apparent low grade of tumor without any known metastases.

## CONCLUSIONS

(1) Antral spasm and antral gastritis are a fairly common cause of gastric complaints and present a not dissimilar clinical picture.

(2) Antral spasm must be differentiated from antral gastritis by roentgenologic and gastroscopic examination.

(3) Pathogenesis of antral gastritis is obscure and present classifications are incomplete.

(4) Certain types of antral gastritis are indistinguishable from carcinoma of the stomach; exploration and biopsy are not infallible and gastric resection should be undertaken unless a positive diagnosis can be made.

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# DISPLACEMENT OF MEDIAL EPICONDYLE OF HUMERUS INTO THE ELBOW JOINT

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IT IS THE PURPOSE of this paper to review and to evaluate the results of treatment of 21 consecutive fractures (separations) of the epiphysis of the medial (internal) epicondyle of the humerus with displacement into the elbow joint treated during the period from 1931 to 1944, inclusive, on the Fracture Service of the Presbyterian Hospital, New York City. Each of these cases was either accompanied by a posterior or posterolateral dislocation of the elbow joint or had had such a dislocation reduced by a friend, another physician, or at another hospital before coming to this hospital. Each case, whether of short or long duration after injury, was treated by open operation. Of the 21 cases thus treated, 20 have been followed carefully for years, the average follow-up period being 3.45 years.

A brief discussion of the frequency of the lesion, the anatomy, mechanism of injury, clinical and roentgenologic diagnosis, ulnar nerve involvement, operative and postoperative treatment, as well as follow-up results, will also be presented.

## FREQUENCY OF THE INJURY

The medial epicondyle of the humerus is very frequently injured in children. Quite the opposite is true in adults. The fact that this injury occurs mainly in childhood proves that the cartilaginous plate of the epiphysis offers but a weak attachment of the epicondyle to the medial condyle. The ossification center for this epiphysis appears on roentgenologic examination about the sixth year, and does not fuse with the diaphysis of the humerus until the 17th year.

Displacement of the medial epicondyle epiphysis into the elbow joint occurs mainly between the ages of seven to 17 years. In the series herein presented 18 of the 21 cases occurred between the ages of nine to 14 years (Table I).

In general, there are two main types of injury to the medial epicondyle epiphysis, namely, (1) mild to moderate separation of the epicondyle from the condyle; and (2) complete avulsion of the epicondyle with downward and lateral displacement and incarceration into the elbow joint. This paper purposes to deal only with the second of these two conditions.

## ANATOMY AND MECHANISM OF INJURY

The medial epicondyle in its normal position lies outside of the elbow joint. The proximal attachment of the medial collateral ligament of the elbow joint is located on the lower margin of this epicondyle. From here it fans-out dis-

tally to become attached to the medial margin of the coronoid and olecranon processes and the medial margin of the greater sigmoid fossa of the ulna. Also, attached to this epicondyle is the common tendon of origin of the flexor-pronator group of muscles (pronator teres, flexor carpi radialis, palmaris longus and the humeral heads of the flexor carpi ulnaris and flexor digitorum sublimis muscles). The surface of this group of muscles is covered by a glistening white, tough fascia. Just behind the epicondyle one finds the ulnar nerve lying in a shallow groove covered with a thin layer of fascia.

The mechanism of the injury is the same as that for a posterolateral dislocation of the radius and ulna upon the humerus, *i.e.*, a fall upon the hand with the elbow completely extended. The suddenness of the violence causes hyperabduction of the forearm bones at the elbow, rupturing the medial collateral ligament or avulsing it from its attachment to the humerus below the epicondyle. At the same time, increased tension is put upon the flexor-pronator group of muscles and this, in turn, is transmitted to the medial epicondyle. Both forces acting together, *via* the ligament and the muscles, pull the epicon-

TABLE I

CASES ACCORDING TO AGE-GROUP

| Age (Years) | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Cases | 1 | 0 | 3 | 2 | 2 | 3 | 4 | 4 | 1 | 0 | 1 |

(18 cases out of 21 fall between the ages of 9 to 14 years.)

dyle epiphysis free and cause it to be displaced markedly downwards and lateralwards. If the epiphysis remains attached to the ulna by the collateral ligament, it, naturally, will tend to follow the displacement of the ulna and radius when these become dislocated. The additional factor of muscular contraction (once the epicondyle is pulled free) tends to make the displaced fragment curl laterally and downwards (Fig. 1). The glistening fascia on the surface of these muscles is unable to contract, and when the underlying muscle fibers do, the result is to turn the fragment as described above, so that in almost all cases the rounded or dome-shaped surface of the epicondyle fragment points in a proximal direction. A few exceptions to this have been noted.

In none of the cases in this series has there been a displacement of the epicondyle fragment into the elbow joint without a concurrent dislocation of both bones at the elbow joint. I do not believe the epiphyseal fragment can be sucked into the joint by a temporary vacuum produced through rupture of the medial collateral ligament and hyperabduction of the ulna on the humerus, as suggested by Patrick. In my opinion, it takes a real dislocation at the elbow with its lateral displacement, ligamentous tear and muscular contraction to draw the avulsed epicondyle into the joint. Even though the patient presents himself without an elbow dislocation, careful questioning will usually elicit the fact that the elbow was deformed immediately following the injury and that a friend or kind "helper" pulled on it, thus, reducing the original dislocation, but leaving the epicondyle within the joint.

The close proximity of the ulnar nerve, as it lies in its groove on the posterior surface of the epicondyle, explains the frequency with which partial or complete palsy of this nerve is seen following such a displacement. This may occur by one of two mechanisms, either stretching of the nerve, or more rarely by displacement of the nerve itself into the elbow joint cavity along with the displaced medial epicondyle epiphysis.

## EXAMINATION

Diagnosis by clinical examination of displacement of the medial epicondyle into the elbow joint is extremely difficult, usually due to the large amount of early swelling and acute tenderness overlying the entire medial aspect of the joint. The condition may be suspected if there is obvious dislocation of both forearm bones and the usual marked prominence of the medial epicondyle cannot be palpated in its normal position on the humerus, and instead, the flattened margin of the condyle itself is felt. However, the displaced epicondyle when not felt in its normal location may have swung posteriorly (pendulum fashion) as a stripped-up periosteal attachment and not be truly in the joint cavity.

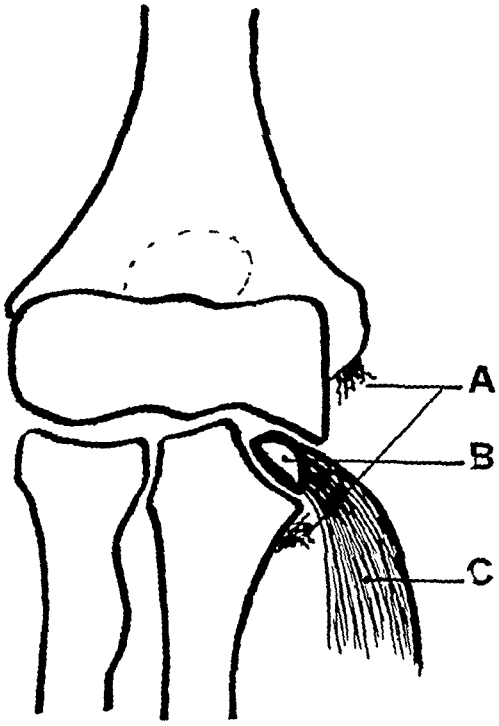



FIG. 1.—Sketch of medial epicondyle displaced into the elbow joint with attached muscles of flexor-pronator group. (A) Torn medial collateral ligament. (B) Medial epicondyle epiphysis. (C) Flexor-pronator group of muscles.

The only sure and safe way to make the diagnosis of, or rule out, medial epicondyle displacement into the joint is on roentgenologic examination. Much too frequently, however, the condition may be missed even on good roentgenograms, and not be picked-up until several weeks after the injury. The reasons for this are mainly two: (1) the physician reading the films being unaware that such a lesion can occur is consequently not on the watch for it; and (2) by mistaking the displaced epicondyle for an ossification center of the trochlear epiphysis (which may have two or occasionally three ossification centers). One should always study the films with this in view if he cannot demonstrate to his satisfaction, or is in any doubt about where the epicondyle is, he should take films of the uninjured elbow in identical positions for comparison. This may save many embarrassing moments later (Figs. 2, 3 and 4).

The lesion is not only of interest from the standpoint of accurate diagnosis, but it is extremely important to make an early diagnosis. Treatment is

obvious and should be immediate when the diagnosis is recognized; but when accurate diagnosis is not made or not recognized till late, proper treatment will either not be carried out or so late that marked impairment of function may follow.

Sometimes difficulty is encountered in obtaining satisfactory anteroposterior views on roentgenograms because of inability of the patient to fully extend the elbow. Rather than attempting to take such a view with the elbow balanced on the tip of the olecranon (which procedure causes distortion on the film of all the bones forming the elbow joint) it would be much better to take



FIG. 2-A 2-B 2-C

FIG. 2.—Anteroposterior roentgenograms showing normal epihpyses of the lower humerus at (A) age 7 years; (B) age 11 years; (C) age 14 years.

two anteroposterior views—one with the lower humerus lying flat on the film and the other with the upper portion of the forearm bones lying flat on the film (Fig. 5). This would give at least one good view of the lower humerus and another of the upper ends of the radius and ulna. Usually, when the medial epicondyle is within the joint, it is situated in a position distal to the lower margin of the trochlea. On the other hand, in younger children with an incompletely ossified trochlear epiphysis where the anatomy is greatly distorted due to elbow dislocation, one must be extremely careful in studying the roentgenograms.

A very important part of the clinical examination should be to test both sensory and motor function of the ulnar nerve. Palsy of this nerve suggests such trauma as contusion or stretching. Although it should put one on his

guard in respect to a lesion of the medial epicondyle, it may occur without the medial epicondyle having been necessarily displaced into the joint. Early recognition of a nerve lesion calls for immediate operation, and possibly transplantation of the nerve, to avoid excess scar formation about it or to release tension upon it.

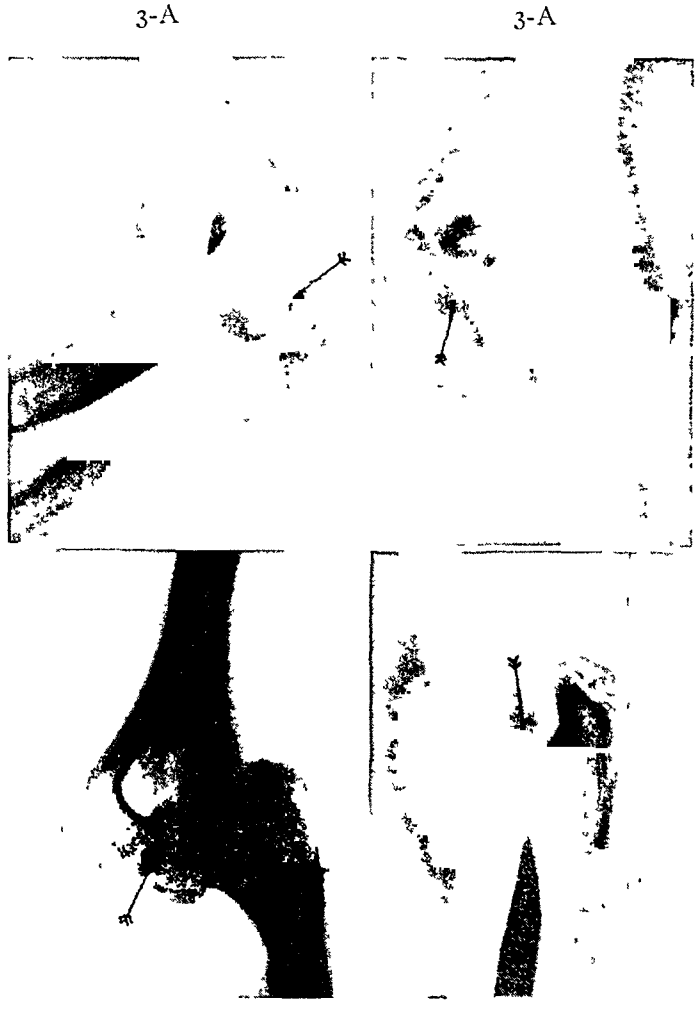



FIG. 3.—Anteroposterior and lateral roentgenograms showing the medial epicondyle epiphysis displaced into the dislocated elbow joint. (A) Case 18. (B) Case 16.

Although treatment in all of our cases has been operative for removal of the incarcerated epicondyle, and we believe this best, Schmier and Patrick have each published reports recently in which they describe conservative methods of withdrawing the epicondyle from the joint space. Schmier's method consists of extending the elbow, wrist and fingers with the forearm fully supinated while at the same time forcibly abducting the forearm at the elbow and with the thumb of the upper hand pulling distally upon the bellies of the flexor-pronator muscles. Patrick's method is very similar except that he

applies faradic current to the flexor-pronator muscles to cause these to contract violently, thereby pulling the epicondyle out of the joint. Even though either of these methods withdraws the epicondyle from the joint space, neither adequately reduces the fragment with its attached muscle mass. Consequently, no fixation of the fragment is possible and early active exercises and use cannot be insti-




FIG. 3.—(C) Case 12. (D) Case 7.

tuted and complete functional return may be impaired. Theoretically, lack of replacement or lack of excision of this epicondyle would offer greater chances of subsequent ulnar nerve palsy.

## ANALYSIS OF CLINICAL CASES

This series comprises 21 cases of displacement of the medial epicondyle into the elbow joint. No comparable series, with adequate follow-up records,

has been previously published, as far as this author has been able to ascertain

Of these 21 cases 13 came to the emergency ward within one-half to three hours following the injury. Twelve showed elbow dislocation on admission. For the past ten years we have tried to train our resident and intern staff to look for this lesion, and, consequently, nine out of the last 11 have been operated upon the day of the injury. The advantages of immediate operation from the standpoint of pathology, physiology and functional recovery are obvious and need not be discussed here. Three cases of the 21 applied for treatment on the second, third, and sixth day, respectively, after the initial injury. Three more applied after two and one-half, three and one-half, and

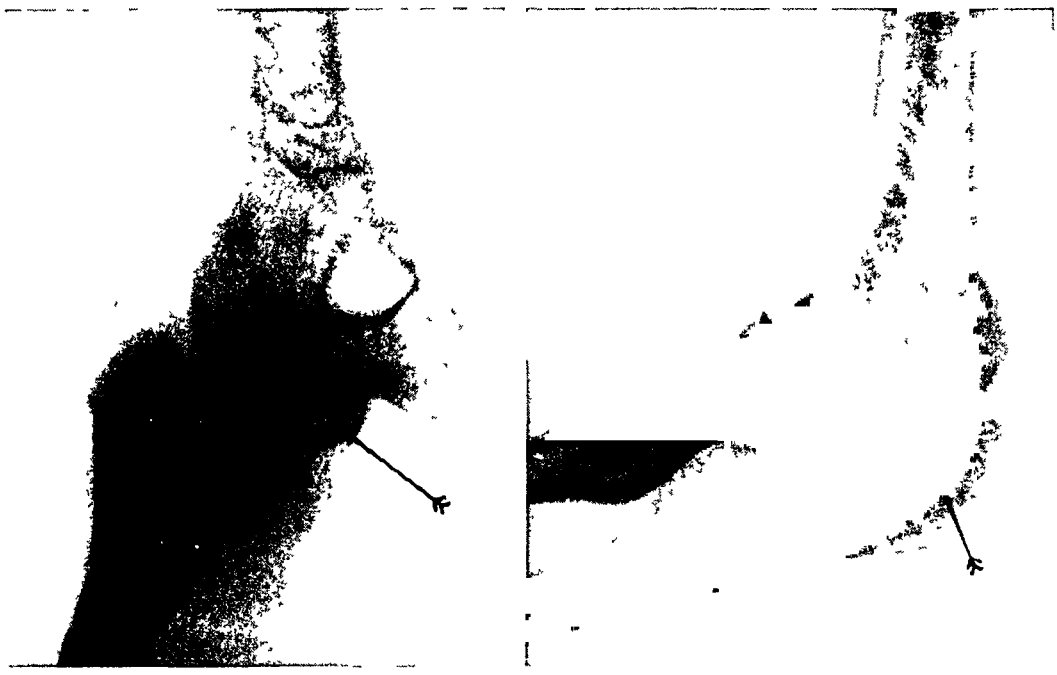


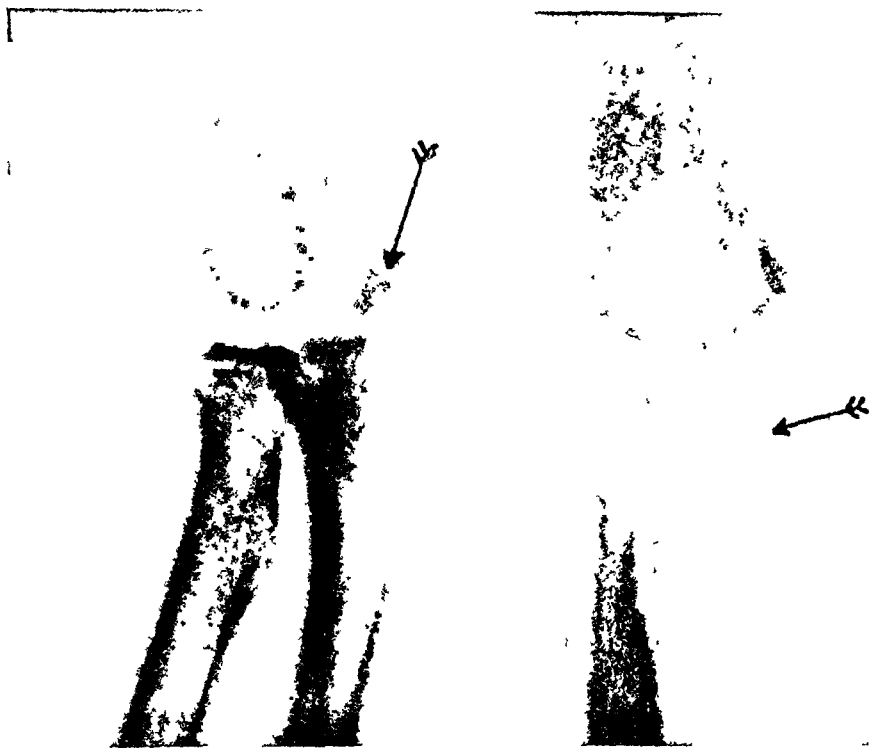

FIG. 3.—(E) Case 15.

four and one-half weeks, respectively. There were two cases that came to us for treatment at two and two and one-half months, respectively. It is of interest to note that of the eight "late" cases four had ulnar nerve palsies.

As previously stated, all 21 cases in this series had sustained an elbow joint dislocation. Eight of these had been reduced before coming to our clinic; two were reduced in our emergency ward; and 11 were not reduced until they reached the operating room. It was, therefore, possible to study the immediate pathology of the dislocation as well as the displacement of the medial epicondyle. In each case an extensive tear of the anterior elbow joint capsule as well as of the brachialis anticus muscle fibers was found. The medial collateral ligament was found to be ruptured in every case. In the immediate cases with ulnar nerve palsy swelling and ecchymosis were found in the nerve.

At operation, the medial aspect of the elbow joint may be exposed either through a longitudinal incision or a transverse one along the flexion crease.

This latter incision gives a better operative scar, but is not adequate for exposure if transposition of the ulnar nerve is necessary. When the joint is exposed, the nearly circular medial aspect of the trochlear process is seen first covered by articular cartilage. Immediately below this is seen the converging fibers of the glistening white fascia overlying the surface of the flexor-pronator muscles. These fibers and muscles curl laterally into the joint cavity just distal to the trochlea. The epicondyle fragment is not seen at this time. However, if this fascia is pulled upon by a mouse-toothed forceps, the incarcerated epicondyle will "pop out" into full view. It can then be reattached to its original site or excised, according to the preference of the operating surgeon.



4-A 4-A

FIG. 4.—Anteroposterior roentgenograms showing the medial epicondyle epiphysis displaced into the reduced elbow joint. (A) Case 21.

There were seven cases associated with ulnar nerve palsy on admission (33 per cent), and one case showed a temporary palsy after operation. One of these cases with ulnar nerve palsy, an 11-year-old colored boy with sickle-cell anemia, was operated upon three days after admission and died on the table of an anesthetic death before the wound could be closed. This is the only case in the entire series that could not be followed. All cases of nerve palsy except for this death and the one postoperative palsy had the nerve treated either by injection of its sheath with saline solution and replacement of the nerve in its normal location (two cases), or by transposition of the nerve subcutaneously to the anterior surface of the medial condyle (four cases). Nerve recovery was complete in all six cases within three and one-half to eight months. In the

postoperative palsy case, the nerve showed complete recovery in two and one-half months. In one of these late cases it was found at operation that the ulnar nerve had been displaced along with the medial epicondyle and lay with it inside the elbow joint proper.




FIG. 4.—(B) Case 10. (C) Case 6.

Treatment of the medial epicondyle *per se* after extraction from the joint and after reduction of the elbow joint (if unreduced) consisted in fastening it to the medial condylar ridge by means of a suture of heavy silk passed through a drill hole in the ridge in 15 cases. In one case, a 17-year-old boy, it was

replaced and fastened with a single stainless steel screw. In five cases the epicondyle was completely excised and the common tendon of origin of the flexor-pronator group of muscles was resutured to the medial condyle with heavy silk. Whether the epicondyle should be replaced and sutured or whether it should be excised and the muscles resutured offers a chance for some interesting speculation. Inasmuch as it was removed in but five cases in this series, and two of these were of over two months' duration, it is difficult to lay down any rules in respect to replacement or excision of the fragment (Fig. 6). It is my impression, however, that by removal in early cases, a quicker return of elbow joint function may possibly be expected provided that postoperative splinting is not carried out longer than two weeks. The irregularity that often

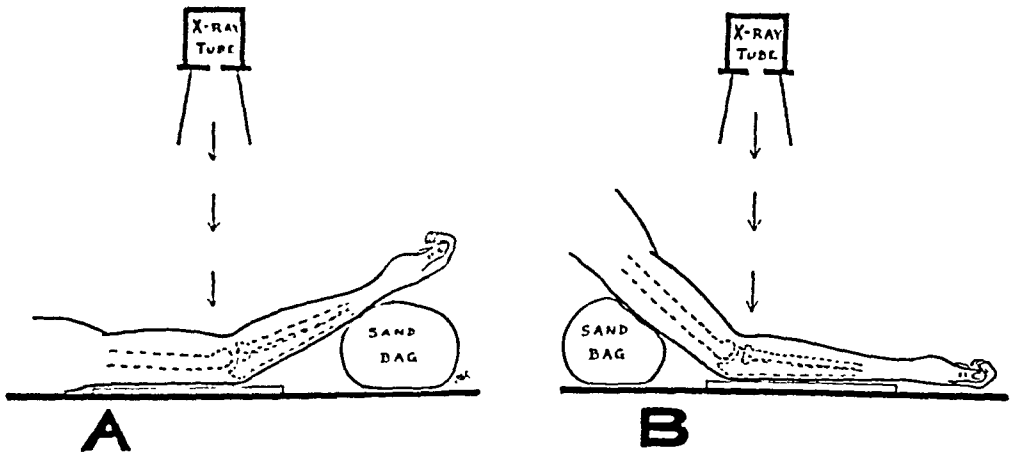
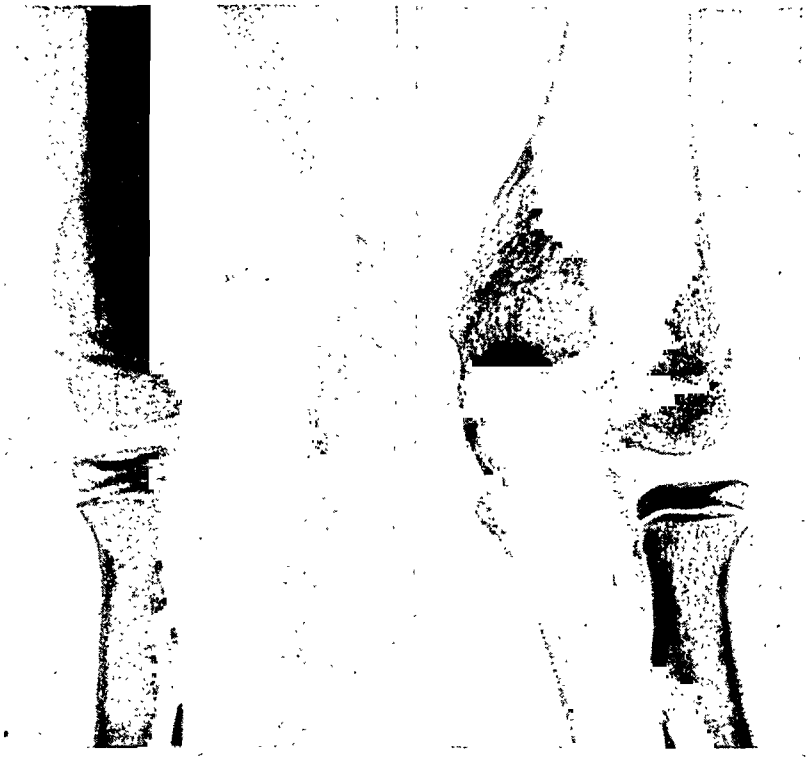



FIG. 5.—Sketch demonstrating method of taking anteroposterior views of a bent elbow in order to prevent distortion. (A) Position with humerus on the film. (B) Position with radius and ulna on the film.

takes place (from growth disturbance) following injury to, and replacement of, the epicondyle, plus the fact that 26.7 per cent reunited only by fibrous union would theoretically be a reason for removing it at operation. On the other hand, it is quite evident that in the cases in which the epicondyle was replaced (whether the epicondyle developed slight irregularity or enlargement) not a single case developed any late ulnar nerve disturbance or loss of function that could be attributed to the epicondyle *per se*. Actually, from the viewpoint of function I believe it makes very little difference whether the epicondyle is replaced or removed.

The only other reason for excision of the epicondyle fragment in addition to those mentioned above would be a purely cosmetic one. Late clinical follow-up examinations show slight to moderate enlargement of the epicondyle on palpation when carefully compared to the uninjured elbow. Occasionally it is found to be slightly sharper in outline if not enlarged (Figs. 7 and 8). In either case, however, the patient or his parents are usually unaware of any of these variations in the anatomy. Although follow-up roentgenograms show somewhat more irregularity and enlargement of the epicondyle than can be



6-A 6-B

FIG. 6.—Follow-up anteroposterior roentgenograms of cases in which the medial epicondyle was excised at operation. (A) Case 19, 6 months after operation. (B) Case 21, 1 year and 4 months after operation.



7-A 7-B

FIG. 7.—Follow-up anteroposterior roentgenograms showing bony union of the medial epicondyle to the condyle with irregularity of the former. (A) Case 14, 1 year and 5 months after operation. (B) Case 12, 1 year after operation.




FIG. 8.—Follow-up anteroposterior roentgenograms showing fibrous union of epicondyle and irregularity. (A) Case 18, 10 months after operation. (B) Case 16, 10 months after operation. (C) Case 11, 6 years after operation. (D) Case 6, 1 year and 8 months after operation.

noted clinically, this at present would appear to be a poor reason for deciding to excise the epicondyle in all subsequent cases in which operation is to be performed.

The most important single factor in the rapidity and completeness of return of function is the length of time that the elbow is kept immobilized after operation. The cases that did best early, and have continued to do so, are those that were immobilized in a posterior moulded plaster splint for *less than two weeks after operation* or had only a sling following operation.

### FOLLOW-UP RESULTS

There have been 21 cases of this type operated upon during the last 13 years, of which 20 have been followed for an average follow-up period of 3.45 years. The longest follow-up period was eight years and nine months, and the shortest was 9.5 months. This latter case could not be followed longer owing to the fact that the patient moved to California. Her result at the time of her last follow-up visit was excellent and the only defect she showed was 10° loss of complete extension at the elbow.

In general, it can be said that the follow-up period has been adequate and that the results quoted are as close to end-results as could possibly be made. All follow-up results have been based on careful clinical evaluation of the patient's extremity and not by letter. These examinations have been very stringent and particular care has been taken to search for any residual defect rather than making the examination purely superficial. Only those patients having a result that could be considered perfect from the standpoint of residual anatomic deformity, function, or economic loss, have been given a rating of "4" in the follow-up of each of these categories. Any patient with a result less than 100 per cent perfect in any of these categories has been given a follow-up rating of "3" or less (Table II).

On summing up the ratings of the various patients it may be said that six have obtained completely perfect results; four have excellent results (this group is made up of cases in which a very slight prominence or irregularity of the medial epicondyle was the only abnormality); nine have received what might be considered good to excellent results, the majority of these showing slight limitation of elbow flexion or extension. One case received what could be considered a fair to good result (Case 5). This case had been previously operated upon, but without the medial epicondyle having been removed from the elbow joint two months before coming to this clinic. None of the cases followed showed any economic loss. In children our evaluation of the economic rating is based on whether or not the child can carry on his usual school activities and activities in sports, *etc.* A good many of these have subsequently finished school and have secured occupations without finding any handicap from the standpoint of the elbow.

In addition to clinical evaluation of the follow-up results of these cases, late roentgenologic examinations have also been made. It is interesting to note that of the 15 followed cases in which the medial epicondyle was replaced at oper-

## TABLE II

TABLE II.

| CASE NO. | AGE | TIME AFTER INJURY (0 = SAME DAY) | ELBOW DISLOC. REDUCED AT: OUTSIDE | EMERGENCY WD. | AT OPERATION | ULNAR NERVE PALSY | TIME BETWEEN ADMISSION & OPER. IN DAYS | FIXATION OF MEDIAL EPICONDYLE | TREATMENT OF ULNAR NERVE | POST-OPERATIVE SPLINTING | OFF TREATMENT AT | ULNAR N RECOVERY AT | FOLLOW-UP: TIME AFTER OPERATION | RATING: ANATOMIC | RATING: FUNCTIONAL | RATING: ECONOMIC | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 4 WKS. | + | | | 0 | 7 | SILK | | 2 WKS | 5½ WKS | | 8¾ YRS | 3 | 3 | 4 | ELBOW RANGE 55-150° |
| 2 | 11 | 0 | | | + | + | 3 | SILK | ? | | | | | | | | DIED. ANESTHETIC DEATH. |
| 3 | 14 | 2 DA. | + | | | + POP | 1 | SILK | | SLING ONLY | 2½ MOS. | 2½ MOS | 4½ YRS | 4 | 4 | 4 | POST-OP. NERVE PALSY FULL RECOVERY IN 2½ MOS. |
| 4 | 13 | 0 | | + | | 0 | 3 | SILK | | 8 DAYS | 2¼ MOS | | 2¾ YRS. | 4 | 4 | 4 | |
| 5 | 15 | 9 WKS. | + | | + | 0 | 7 | EPICONDYLE EXCISED | | 3 WKS | 7 WKS | | 2¼ YRS. | 3 | 2 | 4 | PRIOR OP. EPICONDYLE LEFT IN JOINT. REMOVED AT OP HERE VIA TRANS-OLECRANON APPROACH. ELBOW RANGE 50-115° PRONATION ⅘. BONY BLOCK TO EXTENSION. FULL USE. |
| 6 | 13 | 3 DA. | + | | | 0 | 1 | SILK | | SLING ONLY | 7 WKS | | 1⅔ YRS | 3 | 4 | 4 | |
| 7 | 12 | 0 | | | + | 0 | 0 | SILK | | 2 WKS | 8 WKS. | | 4 YRS | 3 | 3 | 4 | ELBOW RANGE 40-180°. PRONATION ¾. |
| 8 | 9 | 0 | | | + | 0 | 1 | SILK | | 1 MO. | 2¼ MOS | | 10 MOS. | 4 | 3 | 4 | ELBOW EXTENSION LIMITED 10°. MOVED TO CALIFORNIA. |
| 9 | 9 | 3½ WKS. | | | + | + | 6 | SILK | REPLACED INJECTED WITH SALINE | 5 DAYS | 2¼ MOS | 5 MOS | 5 YRS 1 MO. | 3 | 3 | 4 | NERVE FOUND IN JOINT. PRONATION ⅔. FLEXION LIMITED 10°. ULNAR NERVE RECOVERY COMPLETE. |
| 10 | 11 | 0 | + | | | 0 | 0 | SILK | | 18 DAYS | 6½ WKS. | | 4½ YRS | 3 | 4 | 4 | |
| 11 | 12 | 2½ WKS. | + | | | + | 2 | SILK | TRANPOSED | SLING ONLY | 3 MOS. | 5 MOS. | 6 YRS | 4 | 4 | 4 | ULNAR NERVE RECOVERY COMPLETE. |
| 12 | 13 | 0 | | | + | 0 | 0 | SILK | | 9 DAYS | 2 MOS | | 5⅔ YRS. | 3 | 3 | 4 | ELBOW EXTENSION LIMITED 10°. SLIGHT WEATHER ACHE. |
| 13 | 17 | 6 DA. | + | | | + | 3 | 1 SCREW | TRANSPOSED | 3 WKS. | 4½ MOS | 3½ MOS | 3½ YRS. | 3 | 3 | 4 | ELBOW EXTENSION LIMITED 20°. ULNAR NERVE RECOVERY COMPLETE. |
| 14 | 14 | 0 | | | + | 0 | 0 | SILK | | 8 | 2 | | 3¼ | 3 | 4 | 4 | |
| 15 | 12 | 0 | + | | | + | 0 | SILK | REPLACED. INJECTED WITH SALINE. | 13 DAYS | 7 WKS. | 8 MOS | 2⅔ YRS. | 4 | 4 | 4 | ULNAR NERVE RECOVERY COMPLETE. |
| 16 | 13 | 0 | | | + | 0 | 0 | SILK | | SLING ONLY | 6½ WKS | | 3¾ YRS | 4 | 4 | 4 | |
| 17 | 7 | | | + | | 0 | 0 | EPICONDYLE EXCISED | | 4 WKS. | 4½ WKS. | | 2¾ YRS. | 3 | 3 | 4 | ELBOW FLEXION LIMITED 25°. |
| 18 | 14 | 0 | | | + | 0 | 0 | SILK | | 8 DAYS | 3 MOS | | 2½ YRS. | 3 | 3 | 4 | ELBOW EXTENSION LIMITED 5°. |
| 19 | 10 | 0 | | | + | 0 | 0 | EPICONDYLE EXCISED | | 13 DAYS | 3 MOS | | 2⅓ YRS. | 4 | 4 | 4 | |
| 20 | 14 | 0 | + | | | + | 1 | EPICONDYLE EXCISED | TRANSPOSED | SLING ONLY | 4½ MOS | 8½ MOS | 1 YR. | 3 | 3 | 4 | ULNAR NERVE RECOVERY COMPLETE. OCCASIONAL MILD PAIN ALONG NERVE. |
| 21 | 10 | 10½ WKS | + | | | + | 5 WKS. | EPICONDYLE EXCISED | TRANSPOSED | 13 DAYS | 5 WKS. | 4½ MOS. | 1⅓ YRS. | 3 | 4 | 4 | ULNAR NERVE RECOVERY COMPLETE. |

ation and fastened with a silk suture or a screw, 11 of these reunited to the diaphysis of the humerus by bony union (73.3 per cent). This is a somewhat higher percentage of bony union of the epicondyle than is generally supposed to take place after such an injury.

SUMMARY

1. Twenty-one cases of separation of the medial epicondyle of the humerus with displacement into the elbow joint have been reported. All of these cases have been operated upon and all have been followed for an average of over three years, with the exception of one case.

2. Each case of separation of the medial epicondyle with displacement into the elbow joint has been associated with a dislocation of both bones at the elbow joint.

3. The only anatomic deformity detected clinically on late follow-up examinations of these cases is some slight enlargement or irregularity of the medial epicondyle, which in all instances has remained undetected by the patient himself.

4. Bony union of the replaced medial epicondyle as determined by follow-up roentgenologic examination took place in 73.3 per cent of these cases.

5. No late cases of ulnar nerve palsy developed regardless of whether the medial epicondyle was replaced and subsequently healed by fibrous or bony union or with any enlargement or irregularity. Therefore, we feel that the fear of late ulnar nerve palsy which may result from possible growth disturbance in the epicondyle has been greatly exaggerated.

6. All cases associated with ulnar nerve palsy recovered complete function of this nerve.

7. The only symptomatic complaint of any of the followed cases was an occasional instance of slight bad-weather ache. The functional loss of elbow motion was practically minimal, being a limitation of 10° to 15° of flexion or extension in those cases which showed any loss at all. In only two cases was there any greater loss and these were both late cases. However, this loss of function did not interfere in any way with the patient's use or his activities in sports.

8. From the economic standpoint every patient followed showed complete use of the elbow without any handicap whatsoever.

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# A TECHNIC FOR COMBINED MEASUREMENT OF MOTILITY AND ELECTRIC ACTION POTENTIALS IN THE HUMAN INTESTINE

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The Miller-Abbott tube, aside from its multiple uses as a therapeutic and diagnostic instrument, may be used as a convenient means of measuring intestinal motility by connecting its inflated balloon to a recording manometer. Like other similar arrangements this technic is subject to certain known limitations recently detailed by Brody, *et al.*[1] Important among these is the fact that pressure variations so recorded bear no constant relation to true intraluminal pressure changes (Abbott, *et al.*[2]). However, the balloon-manometer method does give empirically reproducible patterns of motility and such measurements, in the intact and in the sick bowel, in conjunction with clinical and roentgenographic data, add considerably to a better understanding of the dynamics of physiologic dysfunction in ileus and other disturbances of motility (Ingelfinger and Abbott[3]). Study of the electrical action potentials of the intestinal wall provides a supplementary dimension of information which may well repay exploitation. In line with the established status of the electrocardiogram and the practical clinical evolution of the electro-encephalogram it appears reasonable to assume that the mural electrogram of the intestine should emerge eventually as a useful adjunct to the other technics now available for the study of intestinal disease. Forster, *et al.*,[4] recently described action potentials recorded from the intact human intestine in conjunction with contractile activity, with particular reference to their legitimacy and their relation to known features of smooth muscle action potential patterns. The present paper outlines a technic for the practical clinical measurement of the intestinal electrogram with simultaneous recording of intestinal motility, built around the Miller-Abbott tube.

## MEASUREMENT OF INTESTINAL MOTILITY

In our apparatus for recording intestinal motility, pressure variations inside the Miller-Abbott tube balloon deflect a mercury column which interrupts a light beam incident upon a photo-electric cell producing alterations of electrical potential which are amplified to activate an ink-writing oscillograph. Details of the amplifier circuit and the manometer photo-electric cell arrangement are shown diagrammatically in Figure 1-a.

The light beam traverses one limb of the manometer and passes through a slot in the wall of a light-tight metal container which houses the photo-electric cell. The slot, ten mm. long by five mm. wide, is centered with respect to the light beam and the element of the cell. The manometer, made of six-mm. bore

glass tubing, is adjustable in a vertical direction and rides snugly in front of the slot in a channel formed by two pieces of felt bordering the slot on either side. Each limb of the manometer is flanked on corresponding sides by a metal millimeter scale visible through a peep-hole in the front wall of the metal case containing the unit and permitting moment-to-moment notation of pressures.

The manometer limb traversing the light beam is connected with the Miller-Abbott tube *via* a length of pressure rubber tubing and a T-tube. In practice, enough air is injected to inflate the balloon fully without distention (25–30 cc.), and the manometer is then adjusted so that the midpoint of the slot bisects (approximately) the current excursions. Adjustment of the amplifier output balance control (Fig. 1-a) similarly permits the excursions of the recording pen to be centered over its mid or neutral position and the observation proceeds.

The recording unit is a cinaudograph oscillograph with an over-all pen excursion of three cm., which writes on a motor-driven paper tape moving 28 mm. per minute. The entire apparatus is mounted on a portable table which is wheeled to the patient's bedside for the recording. The amplifier provides a stable baseline without drift and, considering the very slow frequencies of intraluminal pressure change in the intestine, meets the necessary criterion of passing direct current. The over-all amplitude response, moreover, is linear for manometer deflections within the bounds of the ten mm. light slot which encompasses the usual range of excursion as we have observed it to date with this apparatus.

Some 50 exploratory observations have been made using this apparatus. Aside from studies on five "normal" patients (no gastro-intestinal history) and a case of tropical sprue who were intubated for the purpose, recordings ordinarily were made during the course of diagnostic or therapeutic Miller-Abbott intubations on the surgical services of the Presbyterian Hospital. A few sample records are presented in Figure 2 to indicate the scope of the pattern spectrum encountered. While these observations do not merit detailed discussion in clinical context at the present time, certain general features and clinical correlations are of interest. Rhythmic fast waves at 8–12 per minute may dominate the patterns observed in the normal small bowel (Fig. 2-a) but are usually seen in conjunction with slower waves at 1–1.5 per minute (Figs. 2-c, 2-d). Occasionally, large slow irregular one per minute waves take complete precedence (Fig. 2-b). In paralytic ileus, large dispersed slow components at 0.5–1.0 per minute appear against a baseline background (Fig. 2-e). As seen in one patient (Fig. 2-f) these waves gave way dramatically to a "normal" rhythm at 8–12 per minute accompanying an overnight decompression of a severe inhibitive ileus following drainage of an appendiceal abscess (Fig. 2-g). In harmony with the recent findings of Ingelfinger and Moss,[5] a case of tropical sprue, prior to treatment gave consistent baseline jejunal patterns (Fig. 2-h). Seven weeks later, after dietary and vitamin therapy and marked clinical improvement, the characteristic "normal" pattern of alternating slow and fast rhythmic waves had appeared (Fig. 2-i). Respiratory arti-

facts are occasionally observed (Figs. 2-f and i) and rarely are fairly prominent (Fig. 2-e).

### COMBINED MEASUREMENT OF MOTILITY AND ACTION POTENTIALS

Available methods for recording action potentials from the intact intestine suffer by comparison with the precise technics developed to record electrophysiologic phenomena in other tissues. Observations must be made by remote management with no direct control over the critical factors of electrode placement and contact and with the electrodes bathed in an electrolytic fluid medium which, on theoretic grounds, might well be calculated to produce polarization artifacts. On practical grounds these difficulties are resolved in the empirical demonstration that bonafide electrical action potentials can be recorded from electrodes held in position against the intestinal wall by a balloon, as demonstrated earlier by Forster, *et al.*,[4] and the problem becomes one of devising a suitable electrode bearing balloon.

Our aim was to record action potentials bipolarly from the intestinal wall. The balloon-electrode arrangement we are using at present, and which has proven fairly satisfactory, is shown in Figure 1-b. The electrodes are three-mm. lead disks soldered to lengths of No. 34 enamelled copper wire. The terminal two cm. of wire with the electrode at its tip is attached by rubber cement to the outer surface of the condom rubber balloon. Four electrodes are held in place in this manner at intervals of approximately 1.5 cm. around the mid-circumference of the inflated balloon. The balloon is so constructed, by decreasing the length of condom rubber tubing used, that when collapsed it forms a pleated sleeve around the terminal four cm. of tube proximal to the perforated metal tip rather than a redundant bag. This facilitates passage of the tube tip through the nose with little discomfort to the patient and with minimal electrode mortality. A correlate of this arrangement is the addition of a definite increment to the recorded intraluminal pressure due to the elastic tension of

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FIG. 1-a.—The amplifier circuit and photo-cell manometer arrangement. The amplifier is amplitude modulated, employs the 60 cycle power frequency as a carrier and is equivalent to a D.C. amplifier. Its upper frequency limit is approximately seven cycles per second. The photo-electric cell is in a bridge circuit. Adjustment of the balance control in this circuit varies the negative bias of the control grid No. 1 of the 6L7 tube and hence the amount of current through this tube which in turn varies the amplitude of the 60 cycle carrier. This carrier level is impressed on the push-pull grids of the 6L6's output stage after rectification and appears as a direct current through the oscillograph. The amount of deflection of the pen will depend on the height of the carrier amplitude and a steady deflection of the pen will occur if the carrier level remains unchanged. Hence the balance control can adjust the zero pen deflection. A change in the intensity of the light incident on the photo-cell due to variation of the mercury level in the light beam causes the resistance of the cell element to change and unbalances the bridge circuit which in turn varies the grid bias of control grid No. 1 of the 6L7 and deflects the oscillograph pen.

FIG 1-b.—The electrode-bearing tube tip with balloon collapsed and inflated.

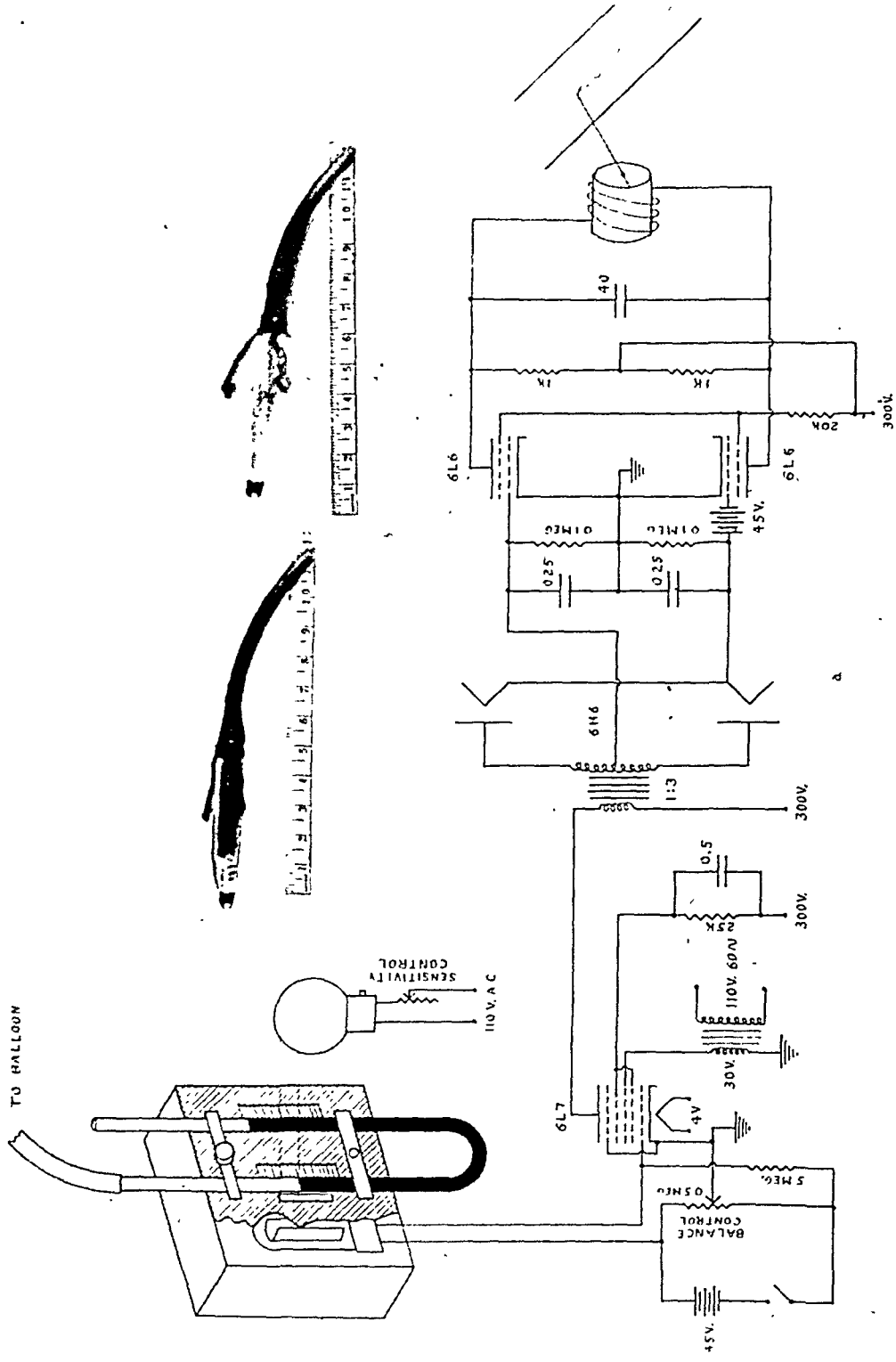

TO BALLOON
SENSITIVITY CONTROL
110 V. A C
6L7
6H6
6L6
6L6
1:3
300V.
300V.
300V.
45V.
45V.
4V
30V.
110V. 60 ~
BALANCE CONTROL
.05MEG
5 MEG.
.025
.025
.01MEG
.01MEG
.5
1K
1K
20K
.02
.1

FIG. 1

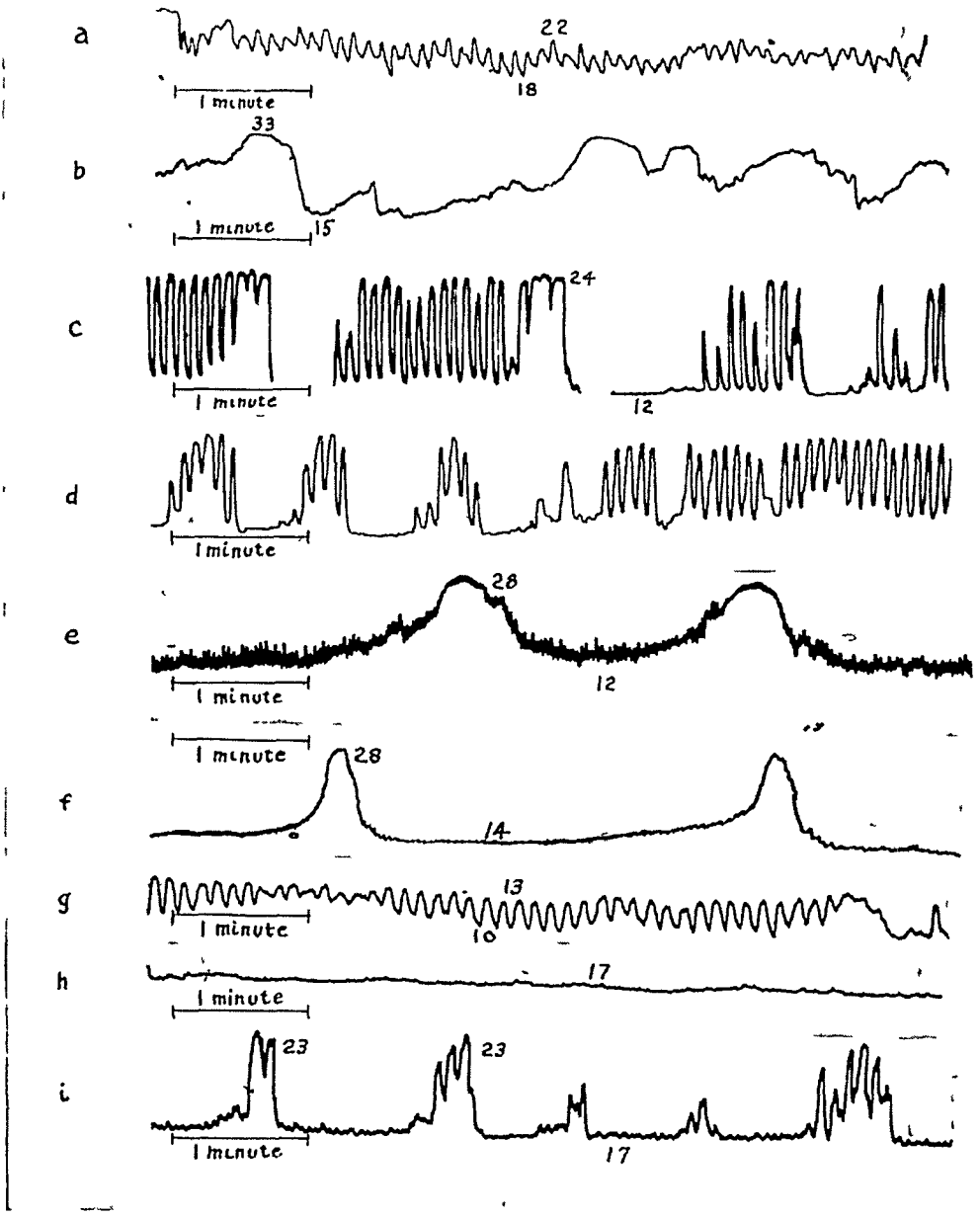



FIG. 2

FIG. 2.—Sample motility patterns from various levels in the small intestine. The numbers above and below the tracings indicate the manometer pressures in millimeters of mercury recorded at the corresponding times.

(a, b, c) Tracings from three "normal" subjects (no gastro-intestinal history), a: Duodenum—typical rhythmic fast waves at 8-12 per minute. b: Proximal jejunum—irregular large slow waves. c: Proximal jejunum—dominant fast rhythm at ten per minute alternating with large slow waves at 1.5 per minute.

(d) Proximal duodenum—similar normal pattern observed two days after ileocolectomy for carcinoma of cecum; abdomen flat, soft, with normal peristaltic sounds.

(e) Distal jejunum—dispersed abnormal large slow components seen in severe post-operative paralytic ileus (acute salpingitis, pelvic peritonitis). The small waves are respiratory artifacts.

(f) Midileum—similar abnormal pattern in paralytic ileus 48 hours after drainage of appendiceal abscess.

(g) Midileum—same patient 24 hours later, after decompression by Miller-Abbott tube. Rhythmic fast waves as seen in normal intestine.

(h) Upper jejunum—abnormal baseline pattern observed in case of tropical sprue early in course of dietary and vitamin therapy.

(i) Upper jejunum—same patient seven weeks later, after marked clinical improvement. "Normal" pattern with typical fast (8–12 per minute) and slow (1–1½ per minute) waves. Small respiratory artifact.

the inflated balloon which under our conditions (20 cc. air) amounts to approximately five mm. of mercury but which does not qualitatively change the motility patterns. In order to stiffen the balloon tip which under these conditions tends to buckle when inflated, a coil of No. 20 steel wire is placed sleeve-fashion around the segment of tube inside the balloon.

The four leads from the balloon are gathered together at its proximal end and under a collar of rubber cement sealing the balloon attachment at this end pass into the air conduit of the double-lumined tube. At the proximal end of the tube the air conduit is attached to a glass Y-tube mounted on a small bakelite panel. The four leads pass through one limb of the Y and thence through a section of rubber tubing which is sealed air-tight around them by a bar screwed over the tube to the panel. Each lead is soldered to an appropriately marked terminal mounted on the panel. The other limb of the Y is connected to a short length of rubber tubing through which the balloon is inflated. The second lumen of the tube, which serves for aspiration or introduction of material into the intestine, is connected at the panel to a short length of rubber tubing to accommodate a 20-cc. syringe.

The intestinal action potentials were recorded on a three channel portable electro-encephalograph in which condenser coupled amplifiers of push-pull input design activate cinaudograph ink-writing oscillographs.* In practice, potentials were recorded on one or two channels and intestinal motility on the third. In order to delineate the detail of the potentials which have considerably higher frequencies than the motility waves, recordings were made at a tape speed of 15 mm. per second. At this speed the slower intraluminal pressure variations are considerably spread out on the record. Visualization of the individual motility waves in their over-all pattern context was facilitated by recording them simultaneously with a separate oscillograph on the slower tape at 28 mm. per minute.

Combined recordings of intestinal motility and action potentials have been made on five patients. Three patients were intubated with the electrode-bearing tube and observations were made at various positions in the proximal small intestine. In each of the other two patients recordings were obtained from the distal colon by inserting the tube into a permanent colostomy.

One's first concern is with the legitimacy of the patterns recorded from electrodes held in contact with the intestinal wall by the Miller-Abbott tube balloon as valid reproductions of electrical discharge originating in the mural tissues. Two signal features of intestinal action potentials emphasized earlier[4] testify as to their validity and have been consistently verified in our observations. These are: (1) the appearance of the potentials before the onset of contractile activity in the intestine; and, conversely, (2) the defervescence of the electrical discharge prior to the cessation of mechanical activity (cf. especially Figs.

* We are indebted to Dr. Paul Hoefer of the Department of Neurology, College of Physicians and Surgeons, who very kindly loaned this equipment to us for these observations.

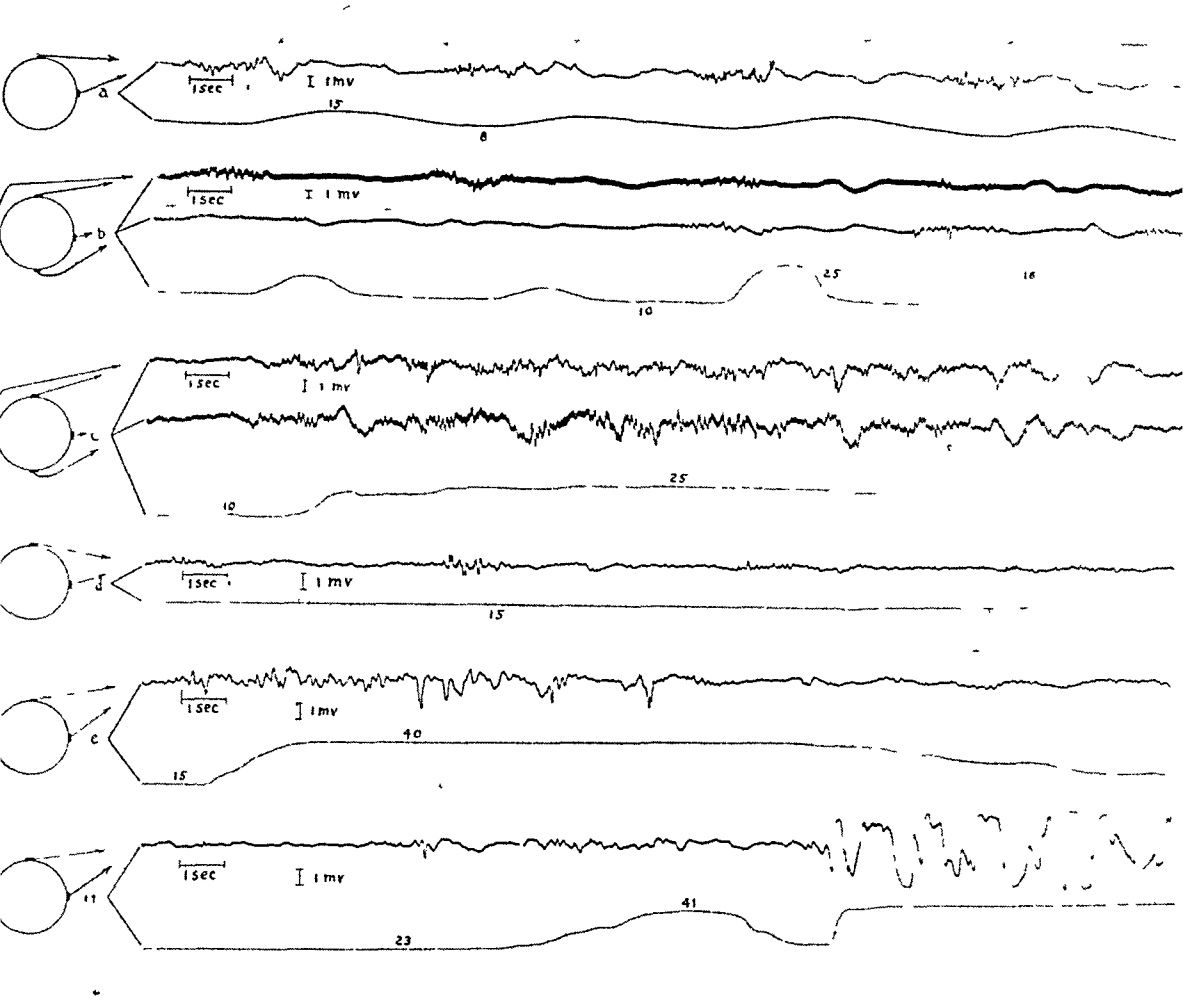



FIG. 3

FIG. 3.—Combined tracings of electrical action potentials and intestinal motility. Electrode arrangement indicated by diagram at left of each set of tracings depicting balloon in cross-section. The numbers above and below the motility record (lower tracing in each instance) indicate manometer pressures in millimeters of mercury.

(a) Proximal jejunum—potentials associated with rhythmic waves at ten per minute. Normal subject.

(b) Similar motility rhythm and potential patterns from duodenum. Carcinomatosis (liver metastases) secondary to carcinoma of transverse colon; chronic pancreatitis.

(c) Proximal jejunum—potentials accompanying slower intestinal contraction. Catarrhal jaundice.

(d, e, f) Sigmoid colon—balloon inserted six inches into permanent colostomy.

(d) Rhythmic electrical discharges in absence of detectable contractile activity. Two weeks after abdominoperineal resection for carcinoma of rectum.

(e) Same patient. Typical slow contractions with potential pattern.

(f) Bona fide action potentials accompanying brief contraction of sigmoid colon succeeded by typical large movement artifacts as balloon was extruded through stoma. Colostomy two years old after abdominoperineal resection for carcinoma of rectum.

3-a and b). The implication is that the potentials do not originate as artifacts in variations of input resistance occasioned by electrode movements at the mucosal surface. By comparison such movement produces rather distinctive patterns (Fig. 3-f). The characteristic association of the potentials with intestinal contraction, moreover, would seem to rule out polarization artifacts as their source since the latter would hardly be expected to meet this limitation. In the later connection it is noted that bursts of potentials appearing independent of any detectable mechanical activity reproduce the patterns associated elsewhere with the onset of contraction (Fig. 3-d).

Potentials recorded from the intestinal wall under the above conditions cover a frequency spectrum from roughly 0.5 cycles per second to 15 cycles per second. Within this spectrum there is a definite tendency to exhibition of several rhythmic maxima. The characteristic prodromal electrical discharge, *e.g.*, is a brief rhythmic burst, usually at 9–12 per second (Fig. 3-a) although it may be as slow as 5–6 per second (Fig. 3-b) or as fast as 15 per second. The emergence of this burst precedes the onset of detectable mechanical activity by approximately 0.75–1.5 seconds. In its subsequent development the potential pattern evolves usually as a slow (0.5–1.0 cycles per second) random complex which fades out frequently at the peak of the intestinal contraction (Fig. 3-a). During sustained activity recurrent fast or intermediate rhythmic discharges are superimposed on these slow drifts often heralding new increments of contraction (Fig. 3-c). These general features of the potential patterns are in harmony with those reported by Forster, *et al.*[4]

Simultaneous tracings from two different areas of the intestinal wall exhibit moment-to-moment variations in relative predominance of discharge and changes in phase relations apparently reflecting a changing orientation of recurrent or prevailing electrical gradients with respect to the recording electrodes (Fig. 3-b and c).

The long latencies between electrical discharge and mechanical contraction are open to question and probably reflect in part both the lag and relative sensitivity of the motility recorder. In this connection, the significance of electrical discharges appearing in the absence of detectable recorded intestinal contraction is not clear (Fig. 3-d). These bursts reproduce the prodromal discharges associated with the onset of contraction. More sensitive means of recording motility might well reveal them as the precursors of luminal intestinal contractions. Their appearance without correlated mechanical activity would implement the logical theoretical allocation of their origin to the rhythmic beating of neurons in the myenteric plexus, already suggested by their clear-cut antecedence over muscular contraction and in harmony with the well-known rhythmic electrical properties of groups of nerve cells elsewhere (Berkson[6]). As such, these rhythmic potentials might well signal the discharge of efferent impulses to the mural smooth muscle the contraction of which, regulated by the impulses, is heralded by the emergence of the ensuing slower action potential complex.

SUMMARY

An apparatus for measuring intestinal motility and a technic for recording electrical action potentials of the intestinal wall in conjunction with motility are described, using an electrode-bearing modification of the Miller-Abbott tube. The action potential patterns are described in relation to contractile activity of the intestine and certain considerations relative to their validity are discussed with the conclusion that they represent bonafide electrical potentials originating in the mural tissues.

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# THE TREATMENT OF COMPOUND FRACTURES IN THE ITALIAN CAMPAIGN

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BECAUSE of the character of the Italian campaign, with its slow but steady advance, delayed occasionally by heavily defended positions, as at Cassino, but never forced to retreat, General Hospitals could be established relatively near to the forward areas and the definitive treatment of the patients undertaken without the fear of an unexpected urgent evacuation. Transportation was relatively rapid and patients were received at these Base Hospitals usually within a week after wounding, frequently within three days. The opportunity was, therefore, afforded to keep the patients under the observation of the same group of surgeons for a period unusually prolonged for war conditions. It is pertinent, therefore, to ask what lessons were learned from this experience which have a bearing on peace-time surgery.

Because this article is based on the personal experience of the writer who was with the British Army a few words of explanation are necessary. It must be remembered that the organization of the Royal Army Medical Corps is different from that of the Medical Corps of the Army of the United States. Details of the differences are not relevant to this article except in so far as they pertain to the matter in hand. During the Middle East and North African campaigns the Royal Army Medical Corps formed specialist teams composed of specially qualified medical officers with trained enlisted personnel and attached to strategically located General Hospitals. Patients requiring the care of such a team were routed to that hospital. This policy was continued during the Italian campaign. Chest teams, faciomaxillary teams, Orthopedic Centers, *etc.*, were placed where it was felt the best care of the wounded would be obtained. An Orthopedic Center consisted of two medical officers, one a Major and one a Major or Captain, two enlisted men acting as clerk and operating room orderly, four masseuses and one occupational therapist. It moved as a unit usually to an already established General Hospital. The writer was officer-in-charge of the 16th Orthopedic Center which was located at Pompeii, at Naples, and finally at Rome. The wounded were received at Pompeii from Anzio and Cassino usually within three or four days from the time of wounding. The initial surgery had already been done by the surgeons of the Casualty Clearing Stations and Field Surgical Units. The

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presenting problem was that of the reparative stage, delayed primary suture and definitive treatment of the fractures. This was also true in Rome, where casualties were sent from the Gothic Line attack.

The liaison between the Forward and the Base Surgeons was in many instances very close, for after a tour of duty at the front the Forward surgeons were posted back to a General Hospital and their places taken by Base surgeons. It will be a lasting regret of the writer that she did not get front line experience. It was through no fault of the authorities who had planned it but each time the opportunity presented, unforeseen circumstances arose to prevent her leaving her particular job.

Another difference between the Medical Corps of the two armies must be remembered, and that is the British shortage of medical personnel in comparison to the American. Closely allied to that fact in determining policies in the care of the wounded was the fact that the United Kingdom was a relatively small island rather heavily occupied by Great Britain and her Allies. Therefore, it was felt wiser not to rush the wounded home but to keep them until no harm could come to them through the inevitable delay in transportation until they reached their final destination. Especially after the Normandy landings, the hospitals in England were crowded to capacity and the doctors greatly overworked. Therefore, patients were retained under continuous supervision longer than was usual in the American forces.

Patients with wounds or injuries involving the long bones and major joints and all complicated problems of fractures and dislocations were sent to an Orthopedic Center. It was neither possible nor necessary for such a Center, with its 200 beds, to cope with all fractures and one of the duties of the orthopedic specialist was to give advice on fracture problems in patients with abdominal, chest or head injuries on other wards. The coöperation and sharing of experiences between the various services not only within the hospital but also in the hospitals of the area was of the utmost value in clarifying and debunking impressions.

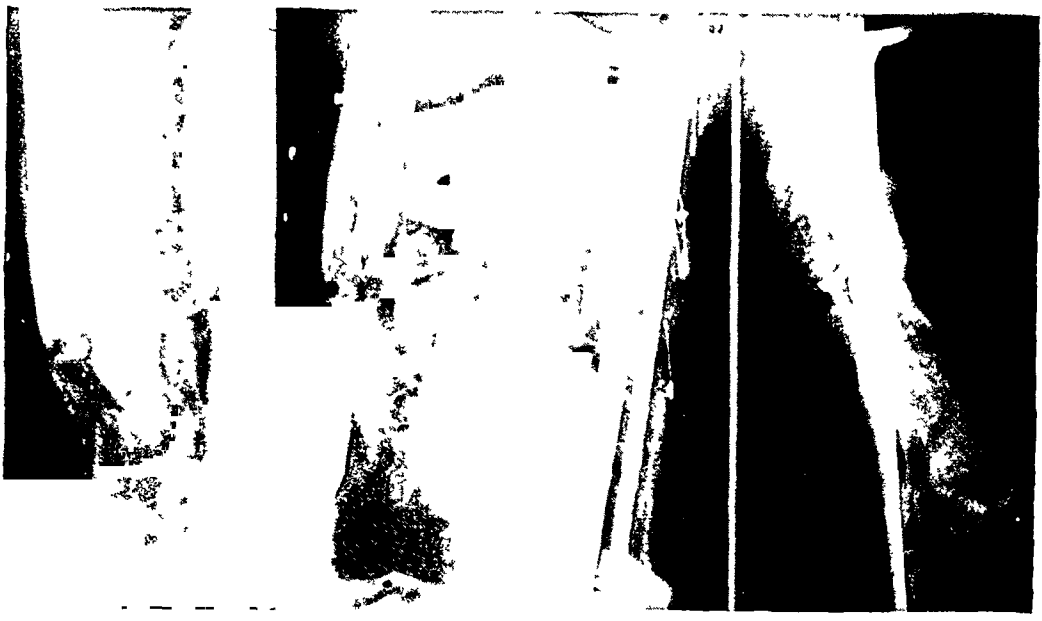
Because of this exchange of opinion and observation, not only between Forward and Base surgeons but also between surgeons of many nationalities but common interests, which the type of campaign allowed, certain principles in the treatment of compound fractures were emphasized anew, others were established.

The sooner compound fractures can be débrided the better. That is a well-recognized fact in civilian surgery. During the press of battle, however, with the casualties flooding the Casualty Clearing Stations and with the inevitable delay in finding the wounded, operations were frequently unavoidably performed 24 hours or more after wounding. Débridement had to be done with the removal of clothing, dirt, shell fragments and devitalized tissue. With careful surgery, adequate immobilization and with chemotherapy these patients reached the Base in most instances without spreading infection and in many instances with clean granulating wounds suitable for delayed closure. Some patients reached the Base Hospital with untouched wounds because




FIG. 1.—(A) Shell wound of thigh, original roentgenograms.
(B) Lateral view.
(C) The same following overenthusiastic removal of fragments and ill-advised internal fixation.
(C Cont'd) The inevitable result two and one-half months later.

of multiple injuries and precarious general condition. For example, two weeks after wounding, pieces of battle dress and a part of a first field dressing which the patient had carried in his hip pocket were removed from the thigh of an officer who had sustained a severe head injury. The day after arrival these were débrided and left open; calcium penicillin sulfathiazole powder insufflated in the wound and penicillin administered systemically. In no case did a systemic infection result.



2-A 2-B 2-B (Cont'd)

FIG. 2.—(A) Shell wound of thigh, on arrival at the Base.
(B) The same 5 weeks later—wounds healed. Callus formation evident.
(B Cont'd) Lateral view.

However, these late débridements were uncommon. Working many times under heavy pressure the Forward surgeons somehow managed to débride meticulously as many as 14 wounds on one patient. Experience proved that the initial operation on compound fractures should strive to create a saucer-like wound, with transverse incisions of the fascia and longitudinal extension of the skin wound. Removal of all loose bone fragments was not only unnecessary but unwise as the fragments provided a needed source of calcium and if the wound became infected could be removed as sequestra later. With delayed suture the chance of infection was sufficiently lessened to permit the retention of loose fragments as a routine procedure (Figs. 1, 2 and 3).

Vaselined gauze was used as a wound dressing but was gradually discarded in favor of fine-mesh gauze which could not act as a plug and did not macerate the skin edges and make delayed suture more difficult. Following operation the extremity was immobilized usually in some plaster of paris encasement, a thoracobrachial for the upper extremity and a modification of the Tobuk splint for the lower.

FIG. 3-B.—The same four weeks later. Fragments incorporated in callus.



FIG. 3-A.—Shell wound of leg, on arrival at the Base.

Unless the condition of the patient or of the extremity indicated it immobilization and dressing were not disturbed until the patient reached the General Hospital. Intermediate and unnecessary dressings, just for a "look-see," increased the risk of secondary infection, and wounds which had been disturbed once or twice in transit did not look so well when they were dressed at the Base. Appearance had to be the criterion for there was no time for bacteriologic studies.

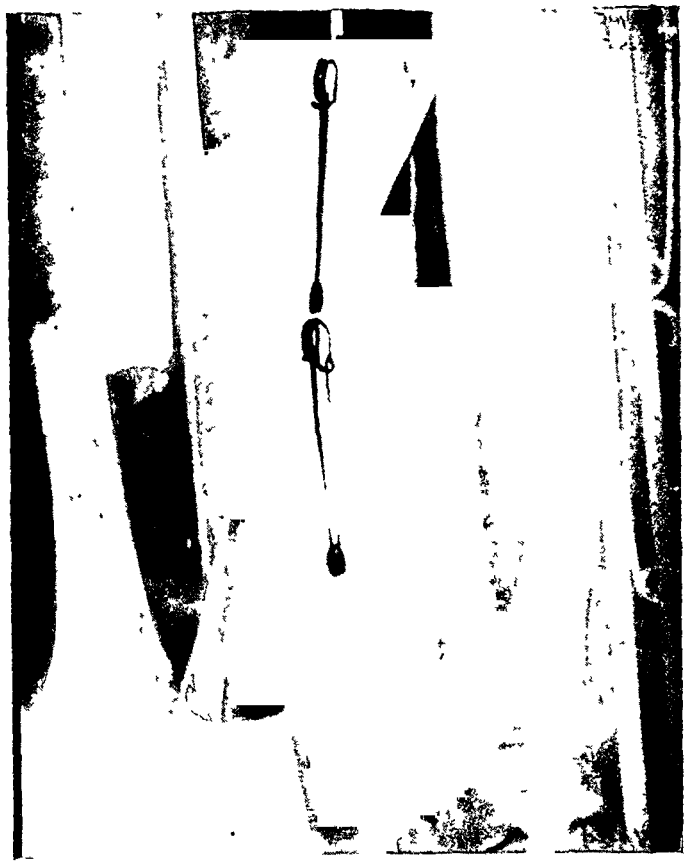


FIG. 4.—Compound fracture of both bones of the leg, on arrival at the Base three and one-half weeks after injury.

On arrival at the Orthopedic Center the wounded were quickly inspected and in most cases of multiple wounds and in all cases of compound fractures of the femur were given transfusions of whole blood. Hematocrit studies in these patients were uniformly low and their response to transfusions was spectacular. The day after arrival the wounded were taken to the operating room *via* the Roentgenologic Department and their wounds inspected. If the wound was covered with bright pink granulation tissue, the skin pinkish-white and elastic, a delayed closure was performed regardless of the existence of an underlying fracture. Meticulous hemostasis was essential with the careful removal of all blood clot. The skin edges could be mobilized by gentle, blunt dissection and surprisingly large areas could be covered. The most satis-

factory suture materials were dermol and silkworm gut, for it was found that thread became moist and gave less satisfactory scars. Inverted mattress stay-sutures under considerable tension, going from deep to superficial tissue and being placed near the ends of the wound first enabled the operator to close the skin edges with interrupted sutures in extremely large wounds. Complete closure was the aim, for those cases gave the highest percentage of satisfactory results. Drains were used only in rare instances. As has been said before the decision to close had to be made on the appearance of the wound on the operating table. There was no time to wait for bacteriologic reports.

Certain wounds, especially those of the buttock, were closed around fine-bore tubes to allow instillation of penicillin. This has been done even in the presence of obvious contamination and surface infection, because it was found that the skin protection, with the increased comfort to the patient, the diminution of tissue fluid loss and the protection from further contamination outweighed the danger of increased infection. Frequently the skin sutures would not hold and had to be removed at subsequent dressings but the wound was always markedly diminished in size. In some cases it amounted to a life-saving measure when coupled with the usual supportive and systemic measures.

Following the treatment of the wound the fracture problem was considered and definitive measures instituted, in some cases skeletal or skin traction, in others plaster of paris splints. Circular plaster encasements were avoided in compound fractures where possible because of the necessary inspection of the sutured wounds. Posterior molded and sugar-tongs splints were found to be time-saving and adequate for leg and ankle fractures. One or both limbs of the sugar-tongs could be pulled out to allow access to the wounds without disturbing the position of the bones.

It was found that earlier reposition of fractures might have been wise. Some patients were delayed in reaching the Base Hospitals and adequate reduction was made difficult, if not impossible. In some instances it was felt that the bone ends might have been slipped together at the time of the initial operation (Fig. 4).

Internal fixation of fractures caused by shell fragments is not feasible in most instances because of the gross comminution of the bone ends. The few cases that seemed to be suitable for plating were operated upon, as a rule, when the compound wound was healed, *i.e.*, the tenth day after suture. The operation was performed through a separate incision, the wound left open for five days and then sutured. It was found by experience that plating through the compounding wound was technically difficult and because the decision to use internal fixation could not be made until the patient was on the table and the wound inspected it was administratively difficult. It proved wiser to make it a planned procedure. Where the method was used it proved satisfactory, with no complications within the first three months.

All sutured compound wounds were dressed in the operating room at five-day intervals until healed. This method began as a matter of expedience because of the shortage of personnel but proved to have definitive advantages.

It was found that wounds that could not be closed completely at the first attempt could frequently be drawn together by a few additional sutures at five days. If not, grafts could then be placed. If there was any evidence of undue tension or of infection sutures could be removed. An anesthetist was always available so any necessary procedure could be undertaken painlessly and unhurriedly. Dressings were done at the end of the operating list, with operating room technic so that the risk of secondary infection was minimized.

Penicillin was not used routinely on all wounded by the British in the Italian campaign, especially in the early days when the supplies were limited. The sulfa drugs were used systemically but frequently in transit the doses were skipped or omitted entirely. The local application of calcium penicillin sulfathiazole powder was used in certain Forward areas and in many of the General Hospitals. In spite of the lack of uniformity in the use of chemotherapy, however, the wounds treated in accordance with surgical principles by experienced surgeons were amazingly clean and the results of delayed primary suture were satisfactory in a high percentage of cases. Sufficient credit can never be given to the excellence of the surgery in the Forward areas. It is undoubtedly true that penicillin gave the necessary impetus to the use of delayed closure in compound fractures caused by war wounds. Its psychologic value was great; its absolute value will emerge when all the data have been assembled and analyzed.

What, then, has been learned? Most of the lessons are not new—early, adequate débridement, immobilization, wound closure as complete as possible within ten days, infrequent dressings, general supportive treatment especially with blood. Even under war conditions the adaptation of the treatment to the needs of the individual must be maintained. Mass production methods should not be used except in periods of intense pressure. Operations, such as internal fixation (Fig. 1), should not be undertaken unless operating room facilities, adequate instruments and qualified surgeons are available. Under stress, when the snowball of work to be done keeps rolling up, standards tend to slip. They should, however, be kept constantly in mind and the effort made to keep them at their highest level.

The writer wishes to express her deep appreciation of the understanding, coöperation and encouragement of Major General Munro, Consulting Surgeon to the British Army; Brigadier W. Rowley Bristow, Orthopedic Consultant to the British Army; Brigadier Harold Edwards, Consulting Surgeon, and Lt. Col. Alan Watson, Orthopedic Advisor to the British Central Mediterranean Forces.

# GUNSHOT WOUNDS OF THE ABDOMEN

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IT WOULD SEEM that no useful purpose could be served by adding another discussion to the deluge of papers which have appeared recently on the subject of abdominal wounds. This seems particularly true since the present report deals primarily with such wounds in civilian experience rather than military service. There are, however, several important features in comparison with Service experience that should be emphasized.

A few years ago the writer reported the results of 101 consecutive gunshot wounds of the abdomen treated at the Indianapolis City Hospital.[1] This included the eight-year period 1930 to 1938. The changes that have been incorporated in general surgical care since that time are justification enough for continuing the study for another eight years into the era of plasma, sulfonamides, and penicillin. It should be recalled that late in the period 1930-1938 sulfonamides were just making their entrance into surgery, the general use of plasma was not to appear for several years, blood banks were unknown and blood was obtained from relatives who were often unwilling.

A continuing study such as this has the advantage that the type of patient, the institution, and the general capabilities of its personnel remain much the same; therefore, a change in medical care can be better evaluated than comparing the results in two dissimilar institutions or communities.

In the previous study (1930-1938) certain conclusions were drawn and recommendations made. These along with the pertinent findings of others in this pre-war period are as follows:

1. Our general mortality of 59.8 per cent for all cases operated upon for perforation of the abdominal cavity seemed excessively high. This, however, was quite in keeping with other large and unselected series. The general mortality throughout the country stood at a challenging 60 per cent. (McGowan,[2] 59.3 per cent; Oberhelman and LeCount,[3] 61.4 per cent; Prey and Foster,[4] 72.7 per cent.)

2. As might be expected, multiple visceral injuries caused a very definite increase in mortality. Thus, when both solid and hollow visceral injury occurred, 88.2 per cent of the patients died.

3. It was pointed out that well over half of our deaths occurred within the first postoperative 24 hours (58.5 per cent), and 45.3 per cent took place during the first 12 hours. But 28.3 per cent were considered to have died of peritonitis or its sequelae.

4. The conclusion seemed obvious that the majority of deaths following perforating gunshot wounds of the abdominal cavity were the result of shock —shock either from excessive blood loss, operative shock, or shock from extensive fecal contamination of the abdominal cavity.

5. The answer to this was intravenous blood in large amounts. How well this was carried out and with what result may be seen from the present report.

During the eight-year period from 1938 to 1946 there were 84 admissions to the Indianapolis City Hospital for gunshot wounds of the abdomen. This was a slight though not significant decrease over the 101 such admissions seen during the previous eight years. There seemed to be no lack of gun-play among the citizens on the home front although this was considerably less accurate than formerly noted. Of the 84 admissions, 15 were found not to have perforations of the abdominal cavity. These nonpenetrating cases need not enter into our discussion since, aside from some rather large retroperitoneal hemorrhages, they presented none of the problems of the perforated viscus. All survived.

There remained 69 cases of abdominal cavity perforation. Of these 25 died, a mortality of 36.2 per cent as compared with the mortality rate in the previous series of 52 per cent.

A further breakdown of the mortality is given in Table I. Here, it will be noted that the mortality was quite reasonable where a single viscus was

TABLE I

MORTALITY COMPARISON

| | 1930–1938 | | 1938–1946 | |
|---|---|---|---|---|
| | Cases | % Mortality | Cases | % Mortality |
| Patients having perforation of abdominal cavity | 87 | 52 | 69 | 36.2 |
| Perforation small intestine (including stomach) | 11 | 45 | 8 | 0 |
| Perforation colon (including rectum) | 12 | 33 | 6 | 33 |
| Perforation solid viscus (pancreas, liver, spleen, kidney) | 10 | 70 | 19 | 5.3 |
| Perforation both colon and small intestine | 13 | 61 | 13 | 61 |
| Perforation colon and /or small intestine and solid viscus | 17 | 84 | 20 | 70 |

involved. Thus, there were no deaths in the eight cases in which the small intestine or stomach alone were perforated. It should not be construed that the anatomic damage was less severe, for such was not the case. Practically all these patients had multiple perforations and one as many as 12 perforations of the small bowel. However, it does mean that the lesion was localized to one given area and organ. This apparently makes for a much better prognosis even though some multiple visceral lesions seem less in extent and with less peritoneal contamination than those of the single viscus. It is also noted that the mortality for wounds involving both hollow and solid viscera was 70 per cent. An extremely high figure is common in all such cases reported.

The improvement from a general mortality of 52 per cent in 1930-1938 to 36.2 per cent for 1938-1946 is quite significant. To what may this be attributed?

First of all, the type of patient treated throughout both periods has remained the same. Four out of five were young adults who have been on the debit side of the municipal ledger all their lives and will continue so.

Fortunate it is for them that no one balances the books or that those to whom their care is delegated do not have to pass on their economic value to the community.

Second, the personnel and the institution have remained relatively constant. There has been a better understanding on the part of the doctors as to the physiologic factors involved in such cases, but the operative procedure has shown little variation.

Third, between the 1930-1938 series and the 1938-1946 series a revolutionary step has been made in the preoperative and postoperative care of the patient—the general use of plasma, sulfanilamide, and penicillin.

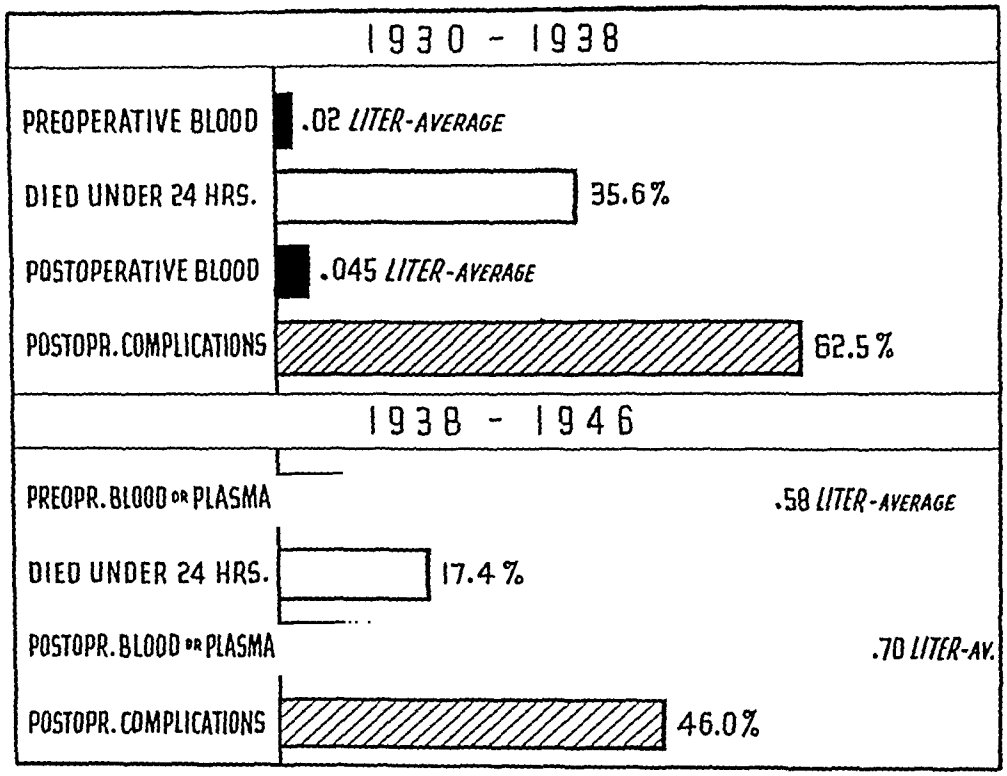



CHART I

PLASMA

Referring to Chart I it will be noted that a negligible amount of blood was given to the first series of patients in the form of transfusions. This all-important phase of therapy speaks for itself when it is noted that 35.6 per cent of these patients died during the first 24 hours after hospitalization. Such deaths can only be attributed to shock—shock from blood loss, extensive peritoneal contamination, or from the operative procedure. A sizable decrease in these 24-hour deaths is noted in 1938-1946 series (17.4 per cent). This improvement is attributed entirely to the increased use of blood and plasma. The amount used averaged .58 liters preoperatively and .7 liters postoperatively, and is small compared with the military use of three and four liters of plasma in similar instances. Undoubtedly some of our civil deaths were the result of insufficient blood or plasma.

### SULFONAMIDES AND PENICILLIN

It has been the hope of everyone dealing with the contaminated peritoneum that the sulfonamides or penicillin would be the long-sought panacea. Such has not been the writer's experience. There is nothing in the present cases to suggest any alteration in the intra-abdominal infection brought about by these drugs. Penicillin or the sulfonamides were never life-savers so far as the peritoneal cavity was concerned. Mortality rates remained identical whether or not they were used.

There was, however, a definite though not too significant decrease in the complications following surgery (Table I). For this reason, and this reason only, penicillin or sulfonamides should be used routinely. Their use as a life-saving measure for the primary lesion only fogs the issue and the surgeon is too apt to put faith in the mystic drug rather than in surgical principles and treatment of potential shock.

In this connection, it might be well to mention the local use of sulfonamide. In the 1938-1946 series, sulfonamide powder was used locally in 13 instances. No benefit was noted. The powder was poured on some supposed critical area, dusted over the exposed intestines or smeared with the fecal contamination over uninvolved loops of bowel. Certainly, such practices are surgically unsound and at best are merely a means of temporarily raising the sulfonamide in the blood to an unpredictable level.[5, 11]

### COMPARISON WITH SERVICE ABDOMINAL WOUNDS

From the standpoint of the actual lesion and the surgical problem, civil gunshot wounds and those in the Service are the same. There seems to be no significant difference in service mortality between small arms wounds and shell fragment wounds.[6,7] Likewise, there are few wounds from high explosives which are more mutilating than a shotgun charge at close range. There were ten such wounds in the last eight years, with five deaths.

The recent mortality records of Service wounds of the abdomen are considerably better than those seen in civil life. There are several obvious explanations for this fact. First of all, there has been insufficient time for the accumulation of any appreciable number of civil cases since the general use of plasma, penicillin, or sulfonamides. Practically all recent reports have been from the Services.

Second, there are a few Service cases who die before they are transported to the Forward Hospital. These deaths are, therefore, not included in any surgical analysis since they are not seen. On the other hand, all such cases are seen in the civil hospital and are included in the mortality analysis. In the field the lag-time between wounding and hospitalization is quite variable. In the survey by Imes[7] it averaged 11 hours. Ogilvie[8] reported that less than half of their cases were operated upon under 12 hours after injury. In the Indianapolis City Hospital cases the interval of injury to hospital averaged .7 of an hour. More than 20 per cent of the deaths occurred during the first 12 hours following injury. Admittedly, the treatment given during this time-inter-

val may not have been ideal from the standpoint of antishock therapy but nevertheless most of these patients would not be included in any military survey. They would have died before reaching the operating unit.

Third, no single Service hospital can follow all their cases to convalescence. A small number die or are lost to follow-up after evacuation from the unit originally reporting operative results.[7,8]

A few of the Service mortality rates which have been reported for penetrating wounds of the abdomen are as follows: Ogilvie, 43.4 per cent; Jarvis, *et al.*, 28.7 per cent; Bradford, *et al.*, 25.5 per cent; Imes, 20 per cent. A review by Sloan on 35 civil cases treated recently reports a mortality of 14.3 per cent.

There is no essential difference in the surgical treatment of civil or military abdominal gunshot wounds. It is a little disappointing that no improved routine has sprung from the large numbers of Service cases which have been reviewed. Plasma was always handy in large quantities and was used in ever increasing amounts. The same cannot be said of the civil institutions where plasma was often not too plentiful. The Service dictum to "exteriorize all wounds of the colon" was greatly overemphasized. There is no reason to exteriorize the simple puncture wound of the large bowel. It can be closed perfectly safely and is followed with a convalescence which is far more satisfactory to the patient. Of course, large rents, devitalization, and retroperitoneal wounds of the colon demand exteriorization.

It would be of interest to know what part overlooked perforations of the gastro-intestinal tract played in the mortality of Service cases. No such figures have been reported. If this incidence approaches that of civil cases, it may be estimated that one-third of the Service deaths were associated with lesions overlooked at the operating table. It is obvious that there will always be overlooked perforations since at times the condition of the patient may not warrant methodical search of all viscera. However, with the increasing use of plasma and control of the patient's shocked state, there should be ample opportunity for a more thorough search and less hurried repair.

With the further realization of the importance of the patient's shock, or his potential shock, as the dominant feature in the care of these cases, it is expected that the general mortality for gunshot wounds of the abdomen will decrease considerably in civil institutions. There will always be a sizable mortality in this type of injury. The resultant mortality will be in direct proportion to the extent of intra-abdominal injury. The cases here reported run quite parallel in this respect to those of Imes, who noted that the type of missile, time-lag before operation, principal viscus involved, and extent of peritoneal contamination were of secondary importance.

## SUMMARY

1. A comparison is drawn between gunshot wounds of the abdominal cavity treated at the Indianapolis City Hospital during the period 1930-1938 and during the subsequent eight years, 1938-1946.

2. The mortality during the recent series was 36.2 per cent as compared with 52 per cent in the former.

3. This improvement is attributed entirely to the realization that shock or potential shock is the principal factor to be considered in treatment. Plasma became available during the second period and was used as much as a somewhat limited supply would permit.

4. The sulfonamides and penicillin also came into general use during the second eight-year period. So far as could be determined, these drugs did not alter the course of the intra-abdominal lesion. Likewise, they did not alter the mortality.

5. The use of a sulfonamide or penicillin is advocated in all these cases but not because of what the drugs can do to the intra-abdominal lesion and its subsequent peritonitis. They are advocated for their ability to decrease the complications following operation. When an operator becomes too conscious of the virtues of sulfonamide or penicillin he tends to lose sight of surgical principles. It would be far better to realize that at the present time nearly half of these patients who are going to die, die presumably of shock during the first 24 hours. After that time a few more will die from overlooked bowel perforations.

6. Military and civil mortality statistics cannot be directly compared because military cases are to some extent selected. Medical care has been essentially the same in both groups.

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# SKIN-GRAFTING THE BURNED DORSUM OF THE HAND

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THE PHYLOGENETIC DEVELOPMENT of the hand of Man has led to specialized adaptation of its skin covering. The skin of the volar surface is thickened, horny, and is capable of withstanding considerable mechanical friction, replacing the epidermal cells lost in such function by a continuous proliferation of new keratinized layers. In addition, the trabeculated subcutaneous fat pad is designed to protect the hand from mechanical shock occurring when moving objects are caught in the palm of the hand, or rough objects are handled. The palmar skin is also capable of contraction, and of folding upon itself in well-outlined patterns of skin lines, to accommodate itself to the decrease in volar surface area with each clenching of the fist. The skin of the dorsum is complementary in function to the palmar skin. It is not subject to excessive friction nor mechanical shock except when the closed fist is used for striking an object or an opponent in fighting. It is, therefore, relatively much thinner than the volar skin and is provided with little or no subcutaneous fat pad. Its resistance to trauma is poor and the skin is quite different in character from the palm. The major feature of the dorsal skin, however, is its high degree of elasticity. This is necessary to accommodate itself to the large increase in surface area when the fist is clenched. It must retract again quickly when the fingers are outstretched and, thus, it exactly counterbalances the contraction and folding of the palm in flexion and the extension of the fingers in extension.

In burns of the dorsum of the hand, the above conceptions of normal structure are necessary to fully understand the burn problem. Since the skin is thin, its elastic fibers are near the surface and are, thus, easily damaged by thermal injury which would not be as harmful on another part of the body. Also, although a second-degree burn may be completely healed without grafting, there may be sufficient damage to these important structures, so that hand function is definitely impaired. In third-degree burns, of course, the elements of local bacterial invasion, with subsequent fibrosis and stiffening, seriously cripple the normal function in this highly specialized area.

Flexion of the fist is a dominant action over extension. This is noted in the increased power of the flexors over the extensors and in the grasping

* The opinions or assertions of the Junior Author are the private ones of the writer and are not to be construed as official or as reflecting the views of the Navy Department or the Naval Service at large.

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FIG. 1

reflex. In addition, protective reflexes, such as covering the face with the hands, result in protection of the palmar surface and exposure of the dorsum. These two factors are undoubtedly responsible for the vast excess in incidence of burns of the dorsum over burns of the palm of the hand. It is, thus, true that in any large number of burns, such as have been encountered during World War II, burns of the dorsum of the hand are exceedingly common. Their consideration as a separate surgical problem is, therefore, desirable.

## CLASSIFICATION

The familiar classification of burns into three "degrees" should be further subdivided when discussing burns of the dorsum of the hand, as each subdivision presents its own special problems of treatment. First-degree burns are subdivided into two groups, second-degree into three groups and third-degree into three groups (Table I). Such a subclassification is helpful in visualizing the progressive stages of injury to the hand by the burn, and will possibly be of some aid in selecting methods of treatment, and in giving an ultimate prognosis. The classification is accompanied by a tabulation of the depth of injury, together with the clinical appearance in relation to the time interval following injury. In a separate column are listed the types of skin-grafts indicated at both early and late stages in the care of the burned hand. These subdivisions are, of course, only rough approximations, but they may serve to guide the surgeon in the conception of the use of the "temporary" graft which is emphasized later in this paper.

## EARLY CARE OF THE BURNED HAND

Scores of writers have emphasized the value of early grafting of burns. In brief, the advantages of such early grafting are those of rapid closure of the open wound produced by the burn. In so doing, the loss of body fluids is stopped and the contaminated, open wound is rendered sterile soon after

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FIG. 1.—(A) Right hand and wrist of a four and one-half-year-old girl who caught her hand in a mangle where it burned for 15 minutes because of failure of the release mechanism. The burn was so deep, and the child's condition was so poor that amputation had been considered by some doctors who saw her. Appearance of the hand when first seen, three weeks after injury.

(B) Granulating wound after active local treatment of the burned area by frequently changed wet dressings of normal saline solution and daily saline baths. All extensor tendons as well as the dorsum of several bones have been destroyed. The metacarpophalangeal joints were completely open and the cartilage sequestrated.

(C) Appearance after use of small deep grafts as "temporary" covering for the raw surface. Bits of bone are still sequestrating, but the wound is nearly healed and the patient is out of the hospital.

(D) Resection of all scar and "temporary" grafts and replacement with the permanent graft, a pedicle flap from the abdomen. The hand and wrist were fixed to the abdomen for 18 days.

(E) Nine months after the burn. The extensor carpi radialis tendon has been reconstructed, utilizing a scar-tissue band. Motion at the wrist is complete. The metacarpophalangeal joints will require arthroplasty at a later date, which, if successful, will be followed by grafts to the extensor tendons of the fingers.

healing has taken place. In burns of the dorsum of the hand, the need for early grafting is even more important than elsewhere on the body, for in few other areas is the fibrosis, which accompanies the prolonged healing of an open wound, so crippling in its late effects.

The above conception of the burn as a wound is important, for there is apt to be confusion as to the surgical care of this type of injury, especially because of the extensive literature on burn care, which somehow carries with it the idea that burns should be treated differently from other wounds. The major difference between burns and other types of wounds is that of surface area of the injury. As such, the problems of fluid loss and resultant changes in body physiology are tremendous, but they do not alter the fundamental conception of the local area of the burn as a wound which involves all of the elements of normal wound-healing physiology. All treatment is, therefore, directed toward closing of the wound at the earliest possible moment.

Methods of care of the local area of the burn will vary from surgeon to surgeon, but the fundamental surgical principles of cleanliness, compression and rest in the treatment of burns, as emphasized by Koch, have met with universal approval. One point should be stressed, however, in relation to the principle of rest. While it is felt that rest is of great value during the first few days of the burned patient's convalescence, the enormous experience of World War II has shown that if hands are splinted for more than a few days, however good the local healing, the stiffening and crippling of the metacarpophalangeal and finger joints far outweighs in importance any advantage to the healing wound surface. Prolonged splinting is definitely contraindicated. In fact, the hands which have done best have been those which have been exercised daily in baths of normal saline, keeping the joints elastic and the fingers movable. Thus, as soon as the body has had time to "wall-off" the damaged area by its normal protective mechanisms, which is ordinarily considered to be from a week to ten days, the exercises are begun. The patient himself finds encouragement as he begins to use his hands again after the fear of stiff and useless members has been established from the time of the burn. Such hands are mobile and flexible, and, after being subjected to the necessary immobilization for a few days at the time of grafting, they quickly regain motion during the postoperative period.

The general care of the patient is all-important and should be governed by the well-established rules for the treatment of burned patients. Nutrition, which is the fundamental basis of all wound healing, may become a special problem in the patient with both hands burned, for he is unable to feed himself from the time of injury. Unless special care is taken to see that he is adequately fed, his qualitative and quantitative food intake may fall far below his requirements. Food needs of the burned patient are greatly in excess of the normal food intake required in everyday life, because of the mass of tissue replacement which is necessary and the constant loss of protein and metabolites through the wound. It is, therefore, desirable that at least four and sometimes six meals per day be given, stressing a high-caloric and high-

protein intake. If the patient's appetite is not good enough to tolerate this forced feeding, supplementary feedings can be given by stomach tube and parenteral therapy of plasma, whole blood and intravenous glucose and amino-acids. The use of amino-acids intravenously is costly and, at best, is a poor substitute for autosynthesis from protein foods taken by mouth, and, thus, has not been extensively used in our experience. The vitamin intake should be kept up in the food and supplemented by additional oral therapy when necessary. The beneficial effects of high-vitamin intake on wound healing have been well shown.

Chemotherapy is given intensively during the first few days of the burn while the body is organizing its defenses against the massive bacterial invasion. Sulfadiazine is the drug of choice by mouth, and penicillin is given parenterally. The use of chemotherapy is then stopped and its help is reserved for acute episodes of infection and for preoperative and postoperative medication at the time of skin-grafting.

## "TEMPORARY" SKIN-GRAFTING

After preparation of the wound for grafting, the surgeon is faced with a choice of grafting methods. It is here that the principle of "temporary" grafting is of importance. By "temporary" graft, we mean the application of skin-grafts, the sole purpose of which is to close the wound. Such grafts are usually removed and replaced with good skin at a later date when the conditions under which the surgery is performed are much more satisfactory. The temporary graft has for its object the most rapid epithelization of the wound and the conservation of donor skin. The grafts used may be "stamp" grafts, cut from a dermatome sheet; "patch" grafts, cut from a free-hand, thick-split graft, which can be easily cut into bits or patches of skin; or "small deep grafts," as described by Davis. Small islands of skin of this type can quickly cover a large granulating area on the dorsum of the hand and forearm with scar epithelium, with a minimum destruction of good donor sites. The chief objection to the use of "small deep grafts" has been their destruction of good skin which may be needed for late repair. For this reason, the "stamp" or "patch" grafts are nearly always preferred. There is one advantage in the "small deep grafts," however, which is the introduction of the elastic elements of the deeper layers of the skin. In addition, their resistance to infection in the granulating area is somewhat higher than the other types, and for this reason, their use is sometimes justifiable. If they are taken from the "swimming-trunk area," a few grafts of this type can often be obtained from a region which is unsuited to split-graft technics, and as it is always hidden by clothing, except in the nude, it thus eliminates disfigurement (Fig. 1).

It is occasionally possible to place the "permanent" graft directly on the granulating surface and secure an excellent end-result at a single operation. This procedure has been advocated for many years by a number of plastic surgeons, and when cases are properly selected, choosing a patient in excel-




FIG. 2

lent condition, with a uniform depth of burn, the single stage application of thick-split skin grafts is certainly the method of choice. All too often, however, the result of such primary use of the large sheets of graft are disappointing. The marginal scar becomes hypertrophic, contracture of the scar-tissue bed causes wrinkling of the graft, webbing occurs between the fingers and secondary operations are then required to obtain a satisfactory result. It would seem obvious then, that the maximum conservation of skin and the best cosmetic and functional result can be obtained by the application of "temporary" grafts for rapid wound-healing, and then late radical resection of all scar tissue and replacement with pliable, elastic skin at a second operation (Figs. 2 and 3). The same working rule applies to second-degree burns which heal without grafting.

One objection has been raised to this two-stage method of repair, and that is the production of contractures as a result of the first operation. These contractures do occur (Fig. 1) but are completely relieved at the second stage of the operation. If the second stage is performed within a few weeks or months, the disability produced by such an interim contracture is negligible.

### LATE SKIN-GRAFTING

There are numerous points which contribute to the good results of skin-grafting the burned dorsum of the hand at a time when the initial burn is healed and the patient is essentially a well individual. In the first place, the procedure is an elective operation. As a result, nutrition can be raised to a high level and the risk of respiratory and other complications can be reduced to a minimum. Second, the operative field is covered by intact epithelium, and if a little time has been allowed for blanching of the scars, the tissues are sterile, with little or no chance of residual bacterial activity in the scar. The advantages of such complete sterility of the wound are very great when compared with the open granulation tissue of the original burn, which is filled with an actively virulent bacterial flora of potential danger at all times. The hand can be incised freely at the late stage, removing all extensions of the scar without the danger of producing a spreading infection which may wreck the delicate mechanisms of the hand. Third, all scar can be removed at the late operation, and the graft is applied on normal underlying tissues. If the graft has been applied directly to granulation tissue or to the yellow base of connective tissue beneath the granulations, there is residual scarring beneath the graft which is inevitable. This scar is inelastic and always restricts the motion of the wrist and fingers to a certain degree. When the graft is applied

FIG. 2.—(A) Left hand and forearm encased in unyielding, hypertrophic dorsal scar and exhibiting many "patch" and "small deep grafts" applied elsewhere. At time of entry, six months after the burn, redness had faded from the scars to a considerable degree, and the danger of latent infection in the tissues was minimal.
(B) All scar and "temporary" grafts removed in one segment.
(C) Dermatome grafts being sutured in place, approximating edge-to-edge.
(D) The permanent skin-grafts in place, with the resected scar placed alongside the forearm for comparison of length.

to normal, sterile subcutaneous tissue, the amount of connective tissue beneath the graft is minimal. Fourth, the margins of the graft can be sutured to good skin under sterile conditions and the tendency for hypertrophic marginal scar is greatly reduced.

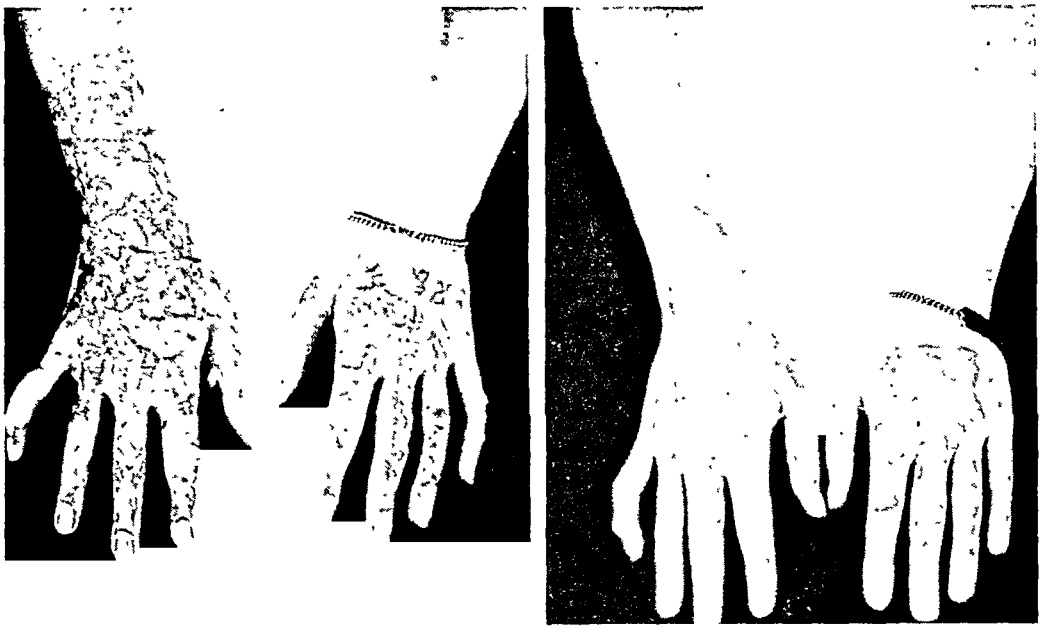


FIG. 3.—(A) Preoperative appearance of a deep second-degree burn which healed spontaneously, but exhibited marked hypertrophic scar formation and restriction of movement.

(B) Postoperative appearance after total resection of the dorsal scar on the right hand and partial resection of the dorsal scar on the left. Dermatome skin-grafts of even thickness produce this flexible, normal appearance and function.

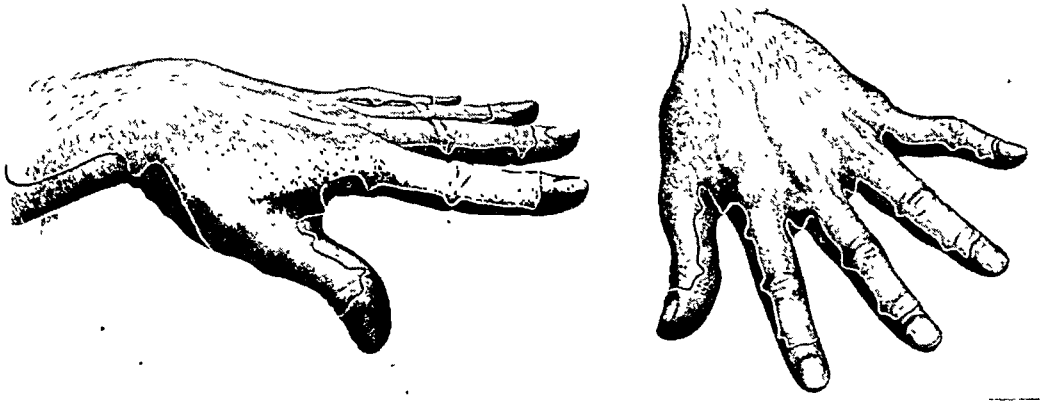


FIG. 4.—Drawing of hand and wrist illustrating principles which have been found useful in planning incisions for resection of scar-tissue and "temporary" skin-grafts at the late stage of reconstructive surgery.

The technic of late skin-grafting of the burned dorsum of the hand follows closely the technic of all other operations on the hand. The hand and arm are carefully prepared the night before operation, paying particular attention

to cleaning and trimming the fingernails, which are often distorted in burn patients and have many pockets and crevices which retain dirt and bacteria. A 20-minute period of soaking in warm soapy water is followed by vigorous scrubbing by the patient himself for ten minutes. The hand and arm are then shaved and scrubbed with soap and water.

At the operating table, the patient is usually given a general anesthesia if the dissection is to be extensive, but local infiltration with one per cent procaine hydrochloride with adrenalin can be used for smaller scar resections. A blood-pressure cuff tourniquet about the upper arm is always used, and gives an excellent bloodless field for dissection if the arm is elevated for several minutes or is wound bloodless with an Esmarch bandage before the tourniquet is inflated. The amount of skin to be needed is estimated before operation and this skin is removed with the dermatome before dissection of the hand is begun.

The dissection of the dorsal scar is started by outlining the scar with an incision about its entire circumference. This outline will be the margin of the future graft, and must be carefully planned, so that the resulting scar will not cross a flexion crease at the wrist or finger-joints at right angles, producing scar contractures (Fig. 4). This is avoided by breaking the longitudinal lines with dart-like extensions at each flexion crease, as described by Brown and McDowell. Bunnell states: "In placing any type of skin graft, care should be used to avoid the median longitudinal line of juncture between the border of the graft and the skin, as this will lead to contracture and keloid. Where such a place seems unavoidable, one can make a cross-cut through the skin border and lay a projecting point of the graft in the gap. The degree of zig-zag thus furnished will help in preventing scar contracture."

Special attention should be given to division of the webs of the fingers to avoid recurring web-formation when the grafts have contracted and their marginal scar has been formed. It has been our practice to overcorrect this web division, splitting well down the volar aspect of the palm, almost halfway from the distal margin of the web to the distal flexion crease of the palm. The dorsal graft is then advanced to this extended point on the volar surface, providing good skin covering deep in the web, and leaving no potential web of marginal scar. Where sufficient care has not been exercised in this reconstruction of the webs, secondary operations for their correction have become necessary. One word of caution should be given in regard to this splitting of the volar skin pad to deepen the webs. The digital nerves lie just beneath the skin, and unless one is working in a bloodless field, they can be severed easily producing anesthesia of the affected finger.

After making the marginal incision completely around the scar, the entire scar-tissue mass is resected, carrying the dissection to the elbow or above, if necessary, to secure complete relaxation (Fig. 2). The dorsal branches of the ulnar and radial nerves lie in the field of dissection and should be preserved unless they were destroyed by the original burn. If they have been partially destroyed, sensation will often return to a more or less satisfactory

degree by overlapping from the volar branches and by some degree of arborization and regeneration of the injured nerves themselves.

After removal of all scar tissue, the tourniquet is released, and all major bleeding points clamped with mosquito hemostats and tied with fine silk or cotton. The arm is then elevated for a few minutes and the tourniquet is reinflated for the remainder of the operation. The graft is sutured in place, securing edge-to-edge approximation where possible, and pressure dressings and splints are applied before the tourniquet is released. The finger tips are left exposed from the dressing so that circulation can be checked.

Where the burn has been deeper and tendons or bones have been destroyed, the thick-split graft is not adequate and a pedicle flap of skin and fat must be applied. For this purpose, the direct one-stage flap from the abdomen is the simplest and best, necessitating a fixation period of 18 to 21 days (Fig. 1). New tendons can be grafted beneath such pedicle flaps and the joints of the wrist and metacarpophalangeal areas are supplied with adequate nourishment and mobile soft tissues which give the maximum chance for recovery of function following the burn injury. The application of pedicle flaps distal to the metacarpophalangeal joints is practiced in a few clinics, but the bulk of the flap produces an unsightly and unwieldy finger, regardless of the amount of "thinning" of the flap which is carried out. Grafting extensor tendons to the fingers beneath such flaps on the fingers has been accomplished by a few specially skilled surgeons, but the end-results of such surgery are, in general, very poor.

When all scar contracture has been released in the skin of the dorsum of the hand, there may yet remain contractures of the periarticular ligaments and connective tissue, which greatly limit motion. This is particularly apt to be true when the hand has been splinted on a flat splint with the fingers in extension at the time of the original burn. In this position, the ligaments are relaxed and rapidly contract into tight, firm fibrous bands which lock the fingers in extension. Restoration of motion in such hands requires the application of splints with traction loops about the fingers (Fig. 5). It is useless to try to stretch scar by such splints, and so they are applied only after all scar has been resected and the contracture released as far as possible by skin-grafting. At the time of surgery, capsulotomy is also performed, as recommended by Bunnell. If the extensor tendons are lightly adherent to the underlying bone, traction splints should overcome them. If the adhesions are more dense, complete tenoplasty may be necessary.

The splints employ the principle of fixed traction rather than elastic traction. The tension is increased on the finger loops by thumb-screw tension rods. The tension should be increased gradually over a period of weeks, and not made so tight as to cause redness and pain about the joints. This reaction will eventually increase the amount of local fibrosis and defeat the purpose of the splint. Elastic traction irritates the joints by constant minute motions under tension, and local tissue reaction occurs, with subsequent fibrosis. The splints are removed daily for active exercise periods and are then replaced and

adjusted by the patient himself. Massage and passive motion are strictly avoided, for they, too, increase the irritation of the periarticular tissues and the end-results are poor.

## UNSOLVED PROBLEMS

There are a number of pathologic changes which occur as a result of burns of the dorsum of the hand which are difficult or impossible of correction by any known means at this time. One of these residual deformities is the distortion and destruction of the fingernails. The nail bed is warped and twisted

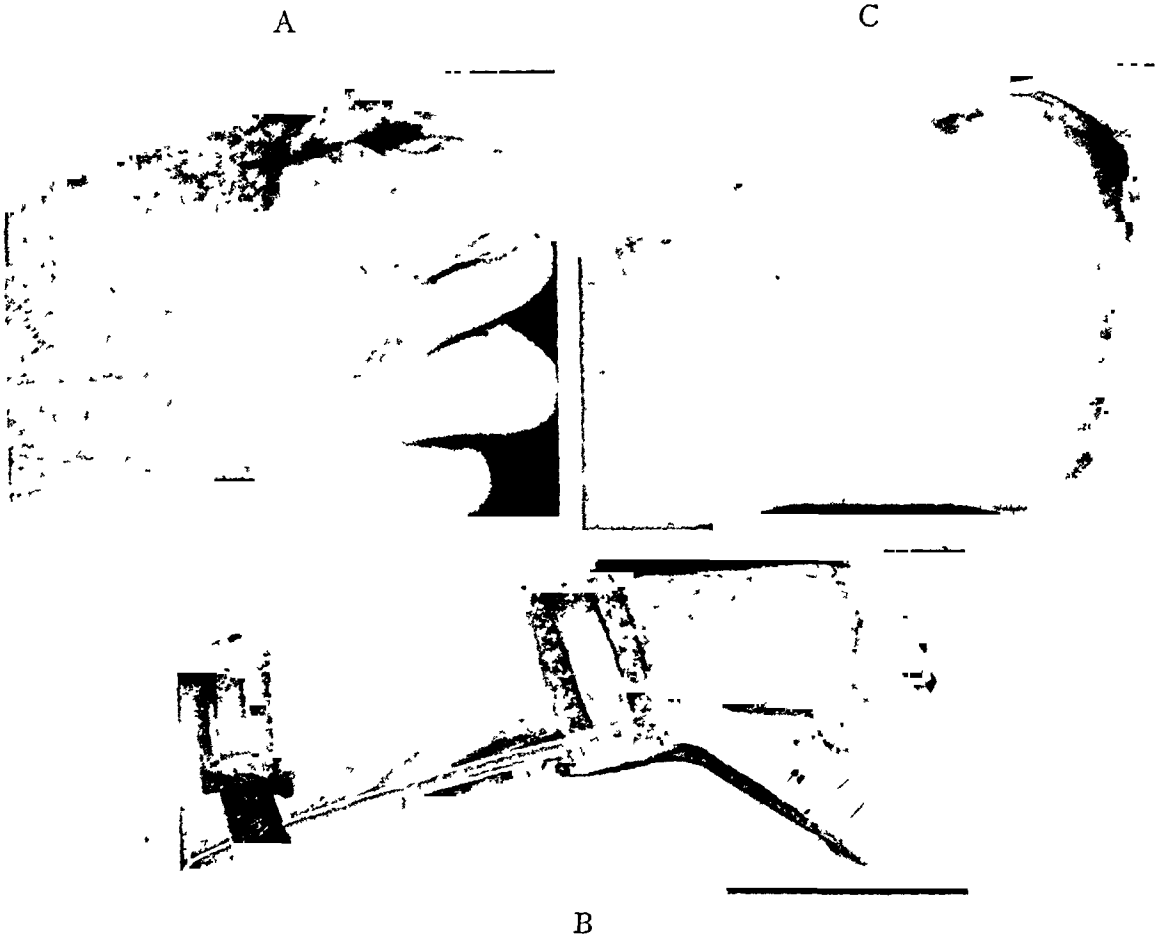



FIG. 5.—(A) Healed second-degree burn with marked restriction of motion at the metacarpophalangeal joints. The extensor tendons were intact.

(B) Splint used in obtaining further flexion of the metacarpophalangeal joints. At operation, capsulotomies were performed on these joints and skin-graft placed over the knuckles where the scar-tissue had become cracked and irritated.

(C) End-result, showing complete restoration of function. The pigmentation of this skin-graft makes it a poor color match for the surrounding skin, in spite of its excellent function.

so that the nail itself becomes a jagged, irregular horn. Removal of the nail gives but temporary relief until the nail grows back again. Its shape is not altered by the removal. To completely destroy the nail bed is difficult, and since there is no subcutaneous tissue to protect it from the underlying phalanx, the healed wound produced by excision of the nail bed becomes painful whether covered with a graft or allowed to heal by scar. Artificial nails have been

TABLE I

CLASSIFICATION AND GRAFTING METHODS FOR BURNS OF THE DORSUM OF THE HAND

## BURNS OF THE DORSUM OF THE HAND
### Classification and Grafting Methods

| DEGREE OF BURN | | DEPTH OF INJURY | | | | | CLINICAL APPEARANCE (*If allowed to heal spontaneously, without graft*) | | | | | | TYPE OF SKIN-GRAFT INDICATED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General Class | Sub-Class | Dermis above epithelial islands | Dermis, down to the epithelial islands | Subcutaneous and areolar tissue | Tendons | Bones and Joints | Immediate | 1 Week | 2 Weeks | 3 Weeks | 4 Weeks | 3–6 Months | Early | Late |
| FIRST DEGREE | A | Slight | None | None | None | None | Marked erythema. | Healed slight redness. | Healed normal appearance | Healed normal appearance. | Healed normal appearance. | No contracture. | None | None |
| | B | Moderate | None | None | None | None | Erythema and moderate bleb formation | Red desquamating | Slight redness nearly normal appearance | Healed normal appearance | Healed normal appearance. | No contracture | None | None |
| SECOND DEGREE | A | Severe | None | None | None | None | Marked bleb formation redness. | Remnants of bleb desquamating Dermis red and tender. | Redness Desquamation | Healed still red. | Healed pale to normal appearance. | Normal appearance. No contracture. | None | None |
| | B | Severe | Moderate | Slight | Slight | Slight | Some whiteness of dermis. Surface wet with body fluids | White, wet. Surface becoming loose. | Whitish-Green, Dead layers separating. Few granulations forming. | Dead layers of dermis fairly dry, separating Pink, healing dermis beneath. | Healed Red Slight tightness when making fist. | Nearly normal appearance. Some slight contracture may occur. | None | Rarely small area of thick-split skin-graft over knuckles may be needed. |
| | C | Total | Severe | Moderate | Slight | Slight | Dead white dermis. Surface wet with body fluids. | White, wet Surface becoming loose. | Whitish-Green, Dead layers separating. Much exudate granulation tissue forming | Most dead tissue separated. All surfaces granulating. Few epithelial islands visible. | Nearly healed by coalescence of epithelial islands. | Much contracture Severely scarred. | "Temporary" Graft At about Third Week<br>*a* Thin Thiersch graft<br>*b* "Patch" or "Stamp" grafts<br>*c* Small deep grafts | Total excision of all scar and replacement with thick-split skin-graft, preferably dermatome graft. |
| THIRD DEGREE | A | Total | Total | Severe | Moderate | Moderate | Dead white or blackened dermis. Surface wet with body fluids. | White, wet. Surface becoming loose. | Whitish-Green, Dead layers separating. Much exudate granulation tissue forming | Most dead tissue separated. All surface granulating. No epithelial islands visible. | Granulating surface. | If healed, severe contracture. | "Temporary" Graft At about Third Week<br>*a* Thin Thiersch graft<br>*b* "Patch" or "Stamp" grafts<br>*c* Small deep grafts | Total excision of all scar and replacement with direct abdominal pedicle flap. |
| | B | Total | Total | Total | Severe | Severe | Dead white or blackened dermis. Surface wet with body fluids. | White, wet. Surface, becoming loose. | Whitish-Green, Dead layers separating. Much exudate granulation tissue forming. Tendons or bones and joints exposed | Much dead tissue. separated, Tendons and bones and joints exposed. | Granulating surface with tendons or bones and joints exposed. | If healed, severe contracture, useless joints and dense cicatrix, cracking and ulcerating. | "Temporary" Graft At about Fourth Week<br>*a* Thin Thiersch graft<br>*b* "Patch" or "Stamp" grafts<br>*c.* Small deep grafts | Total excision of all scar and replacement with direct abdominal pedicle flap. |
| | C | Total | Total | Total | Total | Severe to Total | Charred hand, fingers partially destroyed. | Same, much discharge, beginning demarcation of dead tissue. | Dead tissue beginning to separate. | Active separation of dead tissue. | Active separation of dead tissue. | Unhealed, useless ulcerating stump of a hand. | "Temporary" Graft as soon as any granulating areas are clean enough to receive them. | Pedicle flap designed to give best functional reconstruction for the individual case. |

tried without success, for the underlying bed is too irregular and the na. are a nuisance if the hands are used in any kind of work.

A second unsolved problem is that of loss of the extensor tendon on the dorsum of the finger. As has already been mentioned, the use of pedicle flaps in this region is undesirable, except occasionally for the index finger. The complete covering of all the fingers with a pedicle flap and then grafting new extensor tendons beneath all of these individual flaps is too extensive a series of procedures to undertake, when the end-results are so poor. The finger is pulled into extreme flexion, and often dislocation, when the extensor has been destroyed. This deformity can only be corrected by fusion of the affected joint, usually the proximal interphalangeal, in moderate flexion. The alternative is amputation of the terminal one or two phalanges when they interfere with gripping objects with the fingers. The working man usually prefers the latter solution, especially when the involved digit is the little finger. In many cases, the tip of the finger is so covered with scar, and is so contracted, with useless joints, that it is painful and useless and is better amputated.

The circulation of the burned hand is often poor, and the relief afforded by skin-grafting, while very great, is often insufficient to restore normal circulatory balance, particularly when the hand has been atrophied from long disuse. Such hands remain blue and cold, and the return of function is extremely slow. Since sympathetic block will, at times, give temporary relief of this condition, it may be possible that sympathectomy should be performed in these intractable cases.

Pigmentation of the skin-grafts after application remains an unsolved problem, and all too often a good functional result is marred by the poor color match of the grafted skin (Fig. 5). Many of these will improve with time, but in certain individuals the pigmentation is permanent. Fortunately, such pigmentation occurs rather infrequently. It is much more common in brunettes than in blondes, but can occur in either.

## SUMMARY

The chief characteristic of normal skin on the dorsum of the hand is elasticity. Burns destroy this function and it can be returned only after replacement with new, elastic skin-grafts which replace the inelastic scar. The object of the surgeon is to close the granulating wound as rapidly as possible. Poor marginal scars, contraction of the bed, and the need for frequent secondary revisions have led to the adoption of simple skin-graft technics for "temporary" epithelization of the wound. Late repair can then be performed on a healthy patient as an elective procedure when the wound is sterile, allowing extensive dissection and removal of all scar-tissue. Methods of repair are discussed and several unsolved problems in this field of surgery are enumerated.

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# THE THORACO-ABDOMINAL CASUALTY

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THE SCOPE OF THIS REPORT is a discussion of the thoraco-abdominal casualty in the Forward Hospital, with a presentation of the available data from 903 case records of the 2nd Auxiliary Surgical Group during 1943, 1944 and 1945.

The thoraco-abdominal wound is defined in this report as a wound produced by a missile perforating the diaphragm with entrance into the pleural and peritoneal cavities. Casualties, in which the pleural cavity and peritoneum have been entered by separate missiles without injury to the diaphragm, have been excluded. However, a wound of the so-called "bare area" of the liver, incurred by a fragment entering through the chest and diaphragm has been considered a true thoraco-abdominal wound.

A comparison of the incidence of the thoraco-abdominal wound with respect to all abdominal wounds is of interest. During the period covered by this report, 3,532 operations upon abdominal wounds of all types were performed. The thoraco-abdominal wound comprised 25.5% of this group of abdominal cases.

The great majority of casualties presented are Infantrymen of the U. S. Army and of the Wehrmacht, with a scattered number of Allied British and French soldiers, and a few civilians. The age factor, then, is of little significance, because, of necessity these men were in the young healthy adult male group.

Artillery and mortar fire was responsible for 590 of the thoraco-abdominal wounds, and rifle, machine gun and pistol fire accounted for 245. The few remaining wounds were caused by bomb, mine and grenade fragments.

The pattern of entry of the fragments or bullets in thoraco-abdominal wounds shows that 837 of the missiles entered the abdomen through the thorax, against 66 which penetrated the chest through the abdomen. The entrance wound in the chest was equally distributed on the right and the left sides. Four hundred and eighteen (418) missiles entered through the right, and 419 through the left chest.

For the sake of maintaining continuity in presentation of data, and in discussion of points of practice, not covered by records, the report is divided into the preoperative, the operative and the postoperative phases.

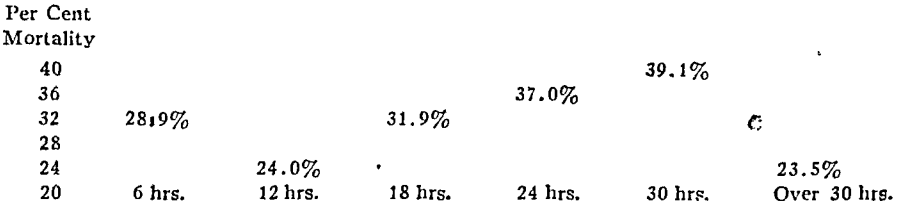
## THE PREOPERATIVE PERIOD

The preoperative phase of the course and treatment of the casualty with a thoraco-abdominal wound embraces the time period from wounding to operation. It is the period of so-called "time-lag." This interval is concerned with the evacuation of the casualty from the battlefield to the hospital, the treatment of shock, the examination and diagnosis.

Time-lag for all patients, and for patients who died, is presented as the number of cases in each six-hour interval up to 30 hours, and for those that came to operation at any time after 30 hours. The percentage mortality shows a progressive increase after the first 12 hours, and drops again for those operated upon after 30 hours. The greater mortality in the period up to six hours is a reflection of the fact that the nearer to the front the Field Hospital is set-up, the higher the expected mortality, because with a short evacuation distance from the line, more of the desperately wounded patients will arrive in the hospital before dying. For example, all the patients in this series with wounds of the vena cava and portal vein are found in this period. The eight casualties that came to operation after 30 hours sustained wounds involving the liver in two cases, the spleen in three instances, the kidney once, and two cases had penetration of the peritoneal cavity without damage to a viscus.

TABLE I

THORACO-ABDOMINAL: 903 CASES—247 DEATHS




When these casualties were received in the first priority surgical hospital from the division clearing station, measures to combat shock and maintain respiratory equilibrium had already been instituted in the form of occlusive dressings to sucking wounds of the chest, injection of morphine, and infusion of plasma. On arrival at the hospital, 455 casualties with thoraco-abdominal wounds had received an average of 525 cc. of plasma each. One hundred and forty-four (144) patients had not received plasma before admission, and the records were missing on this point in 324 instances.

When first seen at the hospital on admission, the degree of clinical shock was recorded by the surgeon as "none," "mild," "moderate" or "severe," or its equivalent. With an increase in the severity of clinical shock on admission, there was a corresponding rise in the percentage of fatalities. There was

a 5.5% mortality in those casualties reaching the hospital without clinical evidence of shock, whereas 59.6% of all cases that arrived in severe clinical shock, died subsequently.

In the shock tent of the hospital, replacement therapy was continued as indicated by the degree of shock and estimated blood loss. The usual practice in those cases requiring replacement treatment was to start an infusion of plasma immediately while waiting for blood to be cross-matched. Thereafter, therapy was continued with blood transfusion. Four hundred and eight (408) patients received an average of 500 cc. of plasma. Two hundred and fifty-two (252) casualties did not receive plasma, and in 353 instances there were no records of it. Similarly, 619 patients received an average of 1100 cc. of blood in the shock tent, while 60 casualties did not get any. Records were lacking on transfusion in 224 instances.

The intelligent regimen of resuscitation and treatment depends on the early recognition of the wound as thoraco-abdominal in extent. Hence, one prompt and thorough examination to discover the site of all wounds, and their position relative to the diaphragm, is paramount. For practical purposes, any perforating fragment which crosses the horizontal zone bounded by the plane of the costal margin and 12th rib below, and the line between the nipple and the angle of the scapula above, may perforate the diaphragm. Where a penetrating wound was present, roentgenologic examination was a necessity. Anteroposterior and lateral positions, preferable in the sitting position for the chest, and with an overexposure of the film for both abdomen and chest, was important to check the position of the retained fragment or bullet, with the site of entry. By this means an effort was made to determine whether or not the zone of the diaphragm had been perforated. Elsewhere roentgenograms were of practical use only in confirming the presence of mediastinal shift associated with an hemothorax or a pneumothorax, and of fractured ribs.

Further clinical examination of the casualty was directed at an evaluation of the cardiorespiratory status—the presence of cyanosis, respiratory restriction due to pain, embarrassing hemothorax or pneumothorax, and excessive tracheobronchial accumulation of blood and mucus. When present, these were treated in the preoperative period by oxygen through a nasal catheter or mask, by intercostal nerve block with procaine, by aspiration of blood and air from the pleural cavity, and by tracheal aspirations with a catheter. The effect of these measures upon cardiorespiratory imbalance and upon the shock state itself was gratifying in a high proportion of cases.

However, in thoraco-abdominal wounds less time could be devoted to stabilization of the cardiorespiratory physiology than in the purely thoracic cases. Of prime importance in combating shock, and saving life in thoraco-abdominal wounds was early operative treatment. There is always the probability that contamination of peritoneum and pleura is present, and this, with continued hemorrhage, constitutes the main causes of continued shock and threat to life. Temporizing and delay in bringing these patients to early operation, as soon as replacement therapy had been started, diagnosis estab-

lished, and measures to combat serious cardiorespiratory imbalance performed, should not be permitted. Even in those patients whose response is poor to adequate treatment, delay in the preoperative tent should, ideally, never exceed two or a maximum of three hours. The operative procedure itself, with control of respiration under endotracheal anesthesia and tracheal aspiration, closure of the chest and diaphragmatic wounds, and, finally, control of hemorrhage and contamination, is the ultimate treatment of shock in these patients. It should not be postponed.

Further clinical examination of the abdomen is relatively unimportant, and often hard to evaluate, because of referred tenderness and pain with the accompanying chest wound, and rigidity associated with respiratory difficulty. Of importance, however, in the preoperative treatment is the introduction of a nasal stomach tube for aspiration of gastric contents. By this means not only is the stomach drained to minimize vomiting during operation, but also the presence of large amounts of blood in the aspirations was of diagnostic significance. Dilation of the stomach with air, to such a degree as to be a factor in the embarrassment of respiration, was not an uncommon finding in these patients, and relief, on occasion, was striking, following aspiration. The stomach tube was fixed to remain in place and drain during operation. In addition, an examination of the voided or catheterized urine for the presence of blood was made in the preoperative period. This gave valuable information as to the course of the missile in relation to the kidney. Before finishing a discussion of the preoperative period it must be emphasized that in some chest wounds, it was impossible to decide whether or not the diaphragm had been perforated. These cases were treated as any suspected wound of the abdomen, and a thoracotomy performed to explore the diaphragm for perforation.

### OPERATIVE PERIOD

With the movement of the casualty from the "shock" tent to the operating tent by stretcher the operative phase of this report is entered. In the majority of instances the patient was operated upon on the stretcher, thus, eliminating the awkward, and not harmless procedure of moving a desperately wounded patient at the outset, and conclusion of the operation. This phase in the care of the thoraco-abdominal casualty deals with the anesthesia, pathology, operative approach, and procedure.

The average length of time under anesthesia for patients with thoraco-abdominal wounds was slightly over 2.5 hours. The majority of inductions were performed with nitrous oxide and oxygen. Ethyl chloride, ether alone, or sodium pentothal were employed to induce the patient in a few instances each. In nearly all cases, maintenance anesthesia was achieved by endotracheal ether and oxygen in a closed circuit. This is the anesthesia of choice. It is impossible to overestimate the value of endotracheal anesthesia in operations upon thoraco-abdominal wounds. The anesthetist, who is an expert in the technic of endotracheal anesthesia, must also appreciate the importance of frequent and thorough catheter aspiration of the tracheobronchial tree. This

was performed before, often during, and always at the termination of the operative procedure. In addition, the value of positive pressure anesthesia, during the period of operation when the thoracic cavity is open, and during closure of the chest when reëxpansion of the lung was required, must be stressed.

There should be no hesitation in the use of bronchoscopy where the above technics have failed in effecting reëxpansion of the lung and reduction of blood and mucus in the tracheobronchial tree. One hundred and ten bronchoscopies are recorded as having been performed at the end of operation in this series of thoraco-abdominal wounds.

Replacement therapy, continued during operation, consisted of blood transfusions, and infusions of plasma and 5% glucose in saline. Six hundred and thirty-nine (639) patients received an average of 1000 cc. of blood during operation, and, in addition, 166 of these were given an average of 575 cc. of plasma each. Seventy-eight (78) patients were each given 1000 cc. of 5% glucose in saline during the course of the operative procedure as a supplement to plasma and blood. During 116 operations, no replacement was deemed necessary. One hundred and thirty (130) records do not treat with this point.

Before dealing with the operative approach and procedure in these thoraco-abdominal wounds, a discussion of the pathology encountered will be presented.

As stated above, the wound of entrance in the thoraco-abdominal casualty was in the thoracic cage 837 times, as against 66 instances in which the abdomen was the site of entry. In most instances, the injury to the chest wall was associated with fractured ribs. The fractured ribs roughly corresponded, to the zone of the diaphragm. In only three instances, of the ribs reported as fractured, was the site above the 6th rib posteriorly or the 4th rib anteriorly. The small size of the target, and the lethal effect of a missile entering the chest from a cephalad direction probably contributed to the paucity of cases with entry wounds in the upper chest.

Likewise, in most instances the described wound of the lung was in either lower lobe, with some cases of injury to the middle lobe on the right, and the lingula of the upper lobe on the left. The pathology in the lung at these sites was described as "contused" "containing hematoma" or as "perforated" or "lacerated." Because of the path of the missile through the lower part of the chest in the diaphragmatic zone, the peripheral portions of the lower lobes, and less frequently of the middle lobe and lingula of the left upper lobe, were injured.

The injury to the diaphragm falls roughly into three categories: the single or double small perforating wounds, the large lacerated wounds, and the avulsion of the diaphragm from its chest wall attachment. Similar to the chest wall, the right and left diaphragms were wounded quite equally. The right diaphragm was perforated in 435 cases and there were 448 wounds of the left. Both diaphragms were wounded in 20 instances. At the time of operation, evisceration of abdominal contents through the diaphragm was recorded to

have occurred in 57 cases. In 17 instances omentum alone protruded into the pleural cavity, but in 40 cases abdominal viscera were found in the chest.

The mediastinum was injured in 30 instances. The heart itself was wounded 14 times and the pericardium alone in 13 cases. The esophagus was injured once, and the posterior mediastinum twice.

In regard to the pathology in the peritoneal cavity, a consideration of the right and left diaphragm with their different underlying anatomic relationship, bears discussion. Wounds of the right diaphragm were associated in 407

TABLE II

FREQUENCY OF WOUNDING AND MORTALITY OF VISCERA AND COMBINATION OF VISCERA IN 903 THORACO-ABDOMINAL WOUNDS

| | Total Cases | Fatal Cases | Per Cent Mortality |
|---|---|---|---|
| Liver | 297 | 35 | 11.7% |
| Spleen | 95 | 10 | 10.5% |
| Liver and kidney | 59 | 14 | 23.7% |
| Spleen and stomach | 43 | 18 | 41.8% |
| Liver and stomach | 30 | 11 | 36.6% |
| Peritoneal cavity only | 26 | 3 | 11.5% |
| Spleen, kidney | 27 | 4 | 14.8% |
| Spleen and left colon | 19 | 4 | 21.0% |
| Left colon | 18 | 6 | 33.3% |
| Spleen, kidney and left colon | 12 | 6 | 50.0% |
| Liver, spleen and stomach | 11 | 3 | 27.2% |
| Spleen, stomach and left colon | 8 | 4 | 50.0% |
| Spleen, kidney and stomach | 9 | 3 | 33.3% |
| Liver and small intestines | 9 | 1 | 11.1% |
| Liver, stomach and colon | 8 | 5 | 62.5% |
| Liver, kidney and right colon | 5 | 4 | 80.0% |
| Liver, small intestine and left colon | 6 | 5 | 83.3% |
| Liver, stomach and biliary tract | 6 | 4 | 66.6% |
| Kidney | 11 | 4 | 36.6% |
| Stomach and left colon | 8 | 2 | 25.0% |
| Spleen and small intestine | 9 | 0 | 00.0% |
| Liver and spleen | 7 | 3 | 42.8% |
| Stomach, small intestine and colon | 8 | 2 | 25.0% |
| Small intestine and left colon | 6 | 3 | 50.0% |
| Liver and right colon | 7 | 4 | 57.1% |
| Kidney and stomach | 4 | 1 | 25.0% |
| Liver and left colon | 3 | 1 | 33.3% |
| Spleen, stomach and pancreas | 3 | 2 | 66.6% |
| All other combinations | 115 | 73 | 63.4% |

(62 in all—mortality of 5 organs or more—100%)

out of 435 times with a wound of the liver. The liver, then, was the organ which took the impact of the missiles entering through the right diaphragm. After the liver, the following organs in order of frequency, were wounded; the right kidney, the colon, the stomach, the small bowel, the duodenum, and the gallbladder. On the left side, the spleen, stomach, and colon were wounded most frequently, and received the impact of most missiles coming through the left diaphragm. In 448 wounds of the left diaphragm, the spleen was injured 272 times, the stomach 167, and the colon in 145 instances. The liver and

left kidney were wounded an equal number of times, followed by the small intestine and pancreas, in order of frequency. A comprehensive list of the frequency of organs and combinations or organs wounded is presented from the records (Table II).

TABLE III

31 TRANSDIAPHRAGMATIC PROCEDURES IN WHICH THORACOTOMY ALONE WAS EMPLOYED

| Procedure | Total Cases | Fatal Cases | Per Cent Mortality |
|---|---|---|---|
| Liver drainage | 148 | 17 | 11.4% |
| Splenectomy | 87 | 9 | 10.3% |
| Splenectomy and stomach suture | 27 | 12 | 44.4% |
| Stomach suture | 23 | 5 | 21.7% |
| Colostomy (left colon flank colostomy) | 12 | 3 | 25.0% |
| Splenectomy and colostomy | 10 | 3 | 30.0% |
| Stomach suture and liver drainage | 7 | 5 | |
| Splenectomy—colostomy and jejunal repair | 6 | 3 | |
| Right nephrectomy and liver drainage | 6 | 2 | |
| Left nephrectomy and splenectomy | 5 | 0 | |
| Splenectomy, stomach suture and liver drainage | 4 | 1 | |
| Splenectomy, stomach suture and colostomy | 3 | 1 | |
| Stomach suture and colostomy | 3 | 3 | |
| Splenectomy and jejunal anastomosis | 2 | 1 | |
| Splenectomy, stomach and pancreas sutures | 2 | 1 | |
| Splenectomy and liver drainage | 2 | 0 | |
| Jejunal repair | 1 | 0 | |
| Left nephrectomy, stomach and jejunal repair | 1 | 0 | |
| Stomach suture, colostomy and liver drainage | 1 | 0 | |
| Left nephrectomy, splenectomy and colostomy | 1 | 0 | |
| Left nephrectomy and stomach suture | 1 | 1 | |
| Stomach suture, colostomy and liver drainage | 1 | 0 | |
| Left nephrectomy, splenectomy and stomach suture | 1 | 1 | |
| Stomach, small intestine suture and colostomy | 1 | 1 | |
| Jejunal suture, colostomy and liver drainage | 1 | 1 | |
| Stomach and jejunal suture | 1 | 1 | |
| Splenectomy, stomach suture, colostomy and liver drainage | 1 | 0 | |
| Left nephrectomy | 1 | 0 | |
| Left nephrectomy and stomach suture and colostomy | 1 | 1 | |
| Colostomy and liver drainage | 1 | 0 | |
| Left nephrectomy, jejunal suture and colostomy | 1 | 0 | |
| | 369 | 0.72 | 19.9% |

TABLE IV

METHOD OF OPERATIVE APPROACH AND MORTALITY IN 903 THORACO-ABDOMINAL WOUNDS

| | Total | Deaths | Per Cent Mortality |
|---|---|---|---|
| Thoracotomy, with transdiaphragmatic celiotomy | 448 | 91 | 20.3% |
| Celiotomy only | 202 | 77 | 38.1% |
| Thoracotomy, then celiotomy | 144 | 36 | 26.0% |
| Celiotomy, then thoracotomy | 74 | 26 | 35.1% |
| Thoracotomy first, with transdiaphragmatic procedure followed by celiotomy | 20 | 7 | 35.0% |
| Thoracoceliotomy traversing chondral arch | 6 | 3 | 50.0% |
| Nonoperated | 3 | 1 | 33.3% |
| Died before end of operation | 6 | 6 | 100.0% |

The anatomic relationships below the diaphragm have a direct bearing upon the operative approach and procedure on the right and left side. A tabulation of the types of approaches, that were used in 903 cases is presented from the records.

Any discussion of methods of approach must be qualified at the onset by saying that no one approach is ideal for all patients, but the judgment of the surgeon, knowing the individual patient, and his own capabilities, will decide the approach to be used by him. In general, where a thoracotomy and celiotomy were both contemplated, the chest procedure was performed first, because the patient stood a celiotomy better after the chest wall and diaphragm had been closed and the lung reëxpanded.

In other words, a more balanced cardiorespiratory system is an important measure in combating shock, and thoracotomy should be performed before, rather than after, a long abdominal procedure.

The practice of stabilizing the chest operatively, by closure of the chest wall and diaphragm, and removal of blood with reëxpansion of the lung, before attempting other procedures is a principle of attack about which there can be little disagreement. The question of how much surgery should, or can be done through the chest and diaphragm, and how much through the abdomen, is open to discussion. In this series, 362 cases with thoraco-abdominal wounds had the entire abdominal procedures performed through the diaphragm. In this group, 31 different combinations of organs were operated upon (Table III).

In further discussion of this topic a consideration of the possibilities of approach when the wound is on the right or on the left side will be debated. Perforating wounds of the chest on the right side, in the upper zone of the diaphragm, are more satisfactorily attacked through a thoracotomy incision, because the diaphragm is much more readily sutured from above, than from below. The presence of the liver makes adequate exploration and suture difficult, and often impossible from below the diaphragm. Similarly, penetrating wounds of the upper zone of the diaphragm, in which the foreign body lies beneath the dome of the diaphragm well within the liver, are more easily handled by the thoracotomy-diaphragmatic route. However, on the right side, perforating or penetrating wounds of the lower zone of the diaphragm in the region of the costophrenic sinus, in which the tract of the missile may well have passed below the liver, should be attacked primarily by a celiotomy approach. Débridement and closure of the chest wall may be done first, or second, depending upon the urgency of the suspected abdominal pathology, and the amount of respiratory embarrassment present. The diaphragm may be closed by either route in the region of the costophrenic sinus, except posteriorly, where closure was difficult, and sometimes impossible from the abdominal cavity. Through the transdiaphragmatic approach on the right side, the field of exploration of the abdomen was limited to the superior surface of the liver, the right kidney, and the hepatic flexure of the colon.

On the left side, the problem is somewhat different, the absence of the liver mass, and the relationship of the fundus and body of the stomach, spleen,

splenic flexure of colon, body and tail of pancreas, and the left kidney to the inferior surface of the diaphragm, not only makes for easy accessibility to these organs through the diaphragm, but also permits greater facility of exploration and suture of the diaphragm from below. Wounds of the left diaphragm carry with them the threat of contamination of the pleural cavity through the diaphragmatic wound by stomach, colon, and small bowel contents.

The data collected from the records cannot be used to show the superiority of either the celiotomy, or the thoracotomy approach, separately in these cases. Depending upon the individual case the magnitude of the abdominal and the thoracic problem, the approach may be best by thoracotomy or by celiotomy, or by both. It may be said, however, in perforating wounds in the upper zone of the left diaphragm, or in penetrating wounds in which the fragment on roentgenologic examination can be demonstrated to lie within the area of the dome of the diaphragm, that these patients may be treated with facility through the thoracotomy-diaphragmatic approach. In these cases the expected injury was a perforation of the spleen, stomach, or kidney, all of which organs are accessible to surgery through the diaphragm. Likewise, wounds of the splenic flexure of the colon may be exteriorized in the flank through this exposure. In addition to these organs it must be stated, that exposure of, and operation upon, most of the transverse colon, the upper part of the descending colon, and the small intestine from the ligament of Treitz to within 18 inches of the ileocecal junction, can be performed through the left diaphragm, depending somewhat upon the habitus of the patient, and the length of the mesenteries.

In those instances of perforation of a hollow abdominal viscus, particularly where there is a diaphragmatic wound of any size, a thoracotomy is distinctly of advantage before a celiotomy, in order to cleanse the pleural cavity of gross contamination. In fact an important part of any thoracotomy entails removal of all foreign material and clot, with a thorough irrigation of the pleural cavity with saline solution. However, in those cases in which a small perforation in the diaphragm is present, and in which contamination is minimal, it must be considered whether it is wise to widely open the diaphragm to attack perforations of hollow organs, thus exposing the pleura and chest wall to wider contamination. These are some of the problems that are met, and which must color the judgment of any surgeon required to meet them.

Further discussion of operative procedure will be limited to the problems peculiar to the thoraco-abdominal wound. Thoracotomies, as performed on these cases, were of four types: (1) A limited thoracotomy achieved by extending the missile wound; (2) a thoracotomy through the area of the wound; (3) a thoracotomy outside the area of the wound; and (4) a so-called combined thoraco-abdominal incision, in which the thoracotomy was extended through the costal arch and down through the abdominal musculature. In the first category are found those in which the chest wound to be débrided was large, and by simple extension of this wound adequate exposure and suture of the diaphragm could be carried out. In Groups 2 and 3, are the majority of cases. They comprised those in which a formal approach was performed, usually

posterolaterally, and either through the rib bed of the 9th rib or the 9th intercostal space. A small proportion of these thoracotomies were performed laterally in the region of the 6th and 7th spaces. Approximately, twice as many of these thoracotomies were performed through the intercostal space as through the bed of a rib. The exposure which gave the best approach to transdiaphragmatic work was the posterolateral one, in the region of the 9th or 10th ribs. The combined approach, of which there were six recorded, was used in two cases in which the costal margin had already been destroyed by the missile. In the four cases in which it was employed as an elective approach one case resulted in a fatal infection, breakdown, and disruption of the wound. Nothing can be said in favor of this type of approach, as an elective procedure.

In this series of cases, records of procedures performed upon the lung included 80 instances in which lung suture was done, and two instances where a segment of the right lower lobe was excised. Records of removal of foreign bodies from the lung were found in nine cases.

The method of opening the diaphragm for exposure of abdominal viscera was not specifically stated in the records, more than that the "wound was extended" or, in case of two wounds, that they "were connected by incision." As stated above, the missile wound or wounds in the diaphragm were utilized in the performance of a more extended opening in the diaphragm. The direction and extent of incision will depend upon the site of the suspected or known viscera wounded, and the amount of exposure necessary.

The closure of the diaphragm is of utmost importance in these cases, both on the right, and on the left. Suture of the left diaphragm is imperative to cut-off the path of contamination and infection from the peritoneal cavity, and to prevent herniation of abdominal viscera into the pleural cavity. It is, likewise, mandatory to close the right diaphragm to prevent the occurrence of bile pleuritis and empyema, and also to keep contamination and infection from invading the pleural cavity. Even in those instances in which a small fragment has penetrated the liver through the diaphragm, it is conservative to explore, suture the diaphragm, and drain the liver, because it is impossible to estimate in every case the size of the diaphragmatic laceration or liver injury from the size of the missile. In some instances, particularly where a rib has been fragmented in passage of a small missile, it is surprising to find the extent of diaphragmatic and liver laceration.

A firm closure in the greatest proportion of these cases was insured by interrupted silk sutures. In those cases in which the diaphragm was avulsed from the chest wall, it was secured by transplantation and suture at a higher level on the chest wall. The phrenic nerve is recorded as having been crushed in 11 instances.

Discussion of the specific treatment of individual organs of the abdominal cavity is not the province of this report. Suffice it to say that wounds of the stomach and duodenum were sutured, wounds of the colon were exteriorized, wounds of the small bowel treated by suture or by resection and an anastomosis, of the spleen by splenectomy, and of the liver by subcostal drainage. Wounds

of the kidney were treated by nephrectomy, only when hemorrhage was persistent, or the pelvis involved, otherwise drainage sufficed. Treatment of the pancreas was by suture and drainage, or by drainage alone. The celiotomy incision was either a right or left rectus, and closure invariably entailed some type of retention suture.

Detailed complete information in respect to closure of the thoracic wound was not present in the records. In general, closure of the thoracic cage was accomplished by approximation of adjacent ribs or intercostal musculature, depending on whether the thoracotomy was performed through the intercostal space or the bed of a rib. In the case of thoracic wall defects, utilization of contiguous musculature in layers was the usual method employed. Closure of the muscle layers of the chest wall was performed with, or sometimes without, closure of subcutaneous tissue and skin. As already emphasized under anesthesia, one of the most important parts of closure is the reëxpansion of the lung by the anesthetist utilizing positive pressure. In order to achieve complete exhaustion of air and fluid in the pleural space, either catheter suction just prior to closing the chest, or needle aspiration after closure were useful.

Three hundred and twenty-six (326) cases were recorded as having been drained by a closed water-trap intercostal catheter or tube. Either a large-sized fenestrated catheter, or tube of equal caliber, with enough rigidity to prevent it from collapsing, was the available material most commonly used for drainage. The site of drainage was usually the posterolateral or lateral aspect of the lower chest through a separate intercostal stab wound. In a few instances a small catheter, in addition was placed in the 2nd interspace anteriorly.

A discussion of the question of whether drainage should be required in these thoraco-abdominal wounds, leads to a consideration of the extent of the lung damage, the defect of the chest wall, the magnitude of the diaphragmatic perforation, and the presence of gross contamination from the wound, or particularly, through the diaphragm from a perforated abdominal viscus. Only in those cases in which the thoracic wall defect is small, and in which lung and diaphragmatic injuries are minimal, without gross contamination, may water-seal intercostal drainage be disregarded as a factor in postoperative expansion of the lung by elimination of pleural blood and air, and control of transient bronchopleural fistulae. The rôle of the intercostal catheter drainage in control of pleural infection is that by elimination of the pleural dead space, the process is limited and localized. It is pertinent to stress that the care of the water-trap drainage in the postoperative period requires constant vigilance on the part of the surgeon, and a thorough knowledge and conscientious attention on the part of the nursing and corpsman staff of a first priority surgical hospital.

### THE POSTOPERATIVE PERIOD

The records of the various phases of postoperative care are incomplete in respect to the various details, so that a discussion must be given of the problems encountered. In general, the care of the patient with a thoraco-abdominal wound entails attention to details of care common to both the chest and the abdominal patient.

Complications recorded in order of frequency were atalectasis, empyema, subphrenic abscess and pneumonia. Bronchopleura fistula was reported four times—twice with empyema, and twice with a bile empyema. Pressure pneumothorax occurred in three instances as a postoperative complication.

The postoperative care of the chest is directed towards maintaining cardiorespiratory balance, promoting expansion of the lung, and removal of blood and air from the pleural cavity to allow full expansion and minimize the chances of pleural thrombus formation. When these patients are brought into the postoperative tent, some will need oxygen and additional blood, as indicated by cyanosis and signs of peripheral circulatory failure. As soon as the patient is conscious, he should be started on a regimen of frequent turning from side to side, with insistence upon deep breathing and coughing. If the patient cannot, or will not cough, and raise the blood and mucus, intercostal block and tracheal aspirations by catheter should be instituted early and repeated as frequently as is necessary in the presence of atelectatic areas in the lungs, or detectable amounts of blood or mucus in the tracheobronchial tree. Often after the first tracheal aspiration the patient will cough and raise without protest. In the event that these methods do not avail in the presence of a pulmonary collapse, bronchoscopy should be employed. There are records of the use of bronchoscopy in 12 instances in the postoperative period. The advantage of the thoracotomy wound alone, without celiotomy, was distinctly appreciated in the postoperative period. The absence of an abdominal incision made for more comfort and for better coöperation from the patient in his important part in lung expansion.

It was the general practice to continue water-trap intercostal tube drainage of the chest for two to three days. Often these tubes did not function efficiently for this period, but became sealed-off after 24 hours. After removal of the tube on the 2nd or 3rd day, and before, in cases without drainage, aspiration of blood and air was done as indicated, daily if necessary. Often a pocket of air was encountered anteriorly, even in those patients who had a lateral or posterolateral intercostal tube. This was evacuated by aspiration with a needle as soon as detected. Morphine in doses larger than 0.25 grain should not be given to these patients, and its use should not be on a routine basis. One-sixth of a grain in many instances sufficed to control the pain in these patients.

A detailed discussion of the postoperative care directed at the abdominal part of the wound will not be entered into in this report, except to emphasize the importance of nasal tube stomach siphonage. All these cases particularly with hollow viscus injury should have a nasal tube stomach drainage for varying periods up to four days, depending upon the reëstablishment of peristalsis to the surgeon's satisfaction. Use of stomach siphonage indiscriminately beyond the period of four days may veil a bowel obstruction, and delay recognition and correction of it.

An accurate knowledge of the daily intake and output of the patients is imperative. During the period in which nasogastric siphonage was in use between 2,000 and 3,000 cc. of 5 per cent glucose in saline was given to these

patients daily. Caution should be exercised in giving a total amount of parenteral fluids in excess of 3,000 cc. daily because of the impaired cardiorespiratory reserve which may exist, and the possibility of producing pulmonary edema. The amount of replacement in blood and plasma given in the postoperative period should be guided by hemoglobin hematocrit and serum protein determinations. A normal level should be reached as soon as possible. The routine employment of vitamins B and C in the postoperative period was considered advantageous.

The use of sulphonamide and penicillin therapy as employed in these cases from the time of wounding through the postoperative period was as follows. Sulphanilamide crystals were placed in the fresh wound in the battalion aid station throughout the entire period. During 1943 and up to May of 1944 sodium sulphadiazine was given parenterally in the postoperative period. After May, 1944, penicillin was instituted and was given intramuscularly in doses which varied between 20,000 and 25,000 units at a three-hour interval, starting in the shock tent and extending through the postoperative period. Before May, 1944, five or ten grams of sulfanilamide crystals were placed in the pleural cavity before closure of the chest in most cases and, after May, 1944, penicillin in amounts ranging from 30,000 to 50,000 units were used similarly in the majority of instances. The use of sulphonamide and penicillin in the abdominal cavity was not as uniform. In most instances their use depended upon the perforation of a hollow viscus. Before May, 1944, five or ten grams of sulphanilimide crystals were left in the peritoneal cavity and, after May, 1944, about one-half of the cases still received sulphanilamide crystals, and one half 50,000 units of penicillin intraperitoneally. Due to the lack of follow-up in the survival patient, it is impossible in this report to give any definite data referable to the relative rôle these drugs played in prevention and control of infection.

TABLE V

MORTALITY RATE—903 THORACO-ABDOMINAL WOUNDS

*(First-Priority Surgical Hospital only)*

| | Total | 1943 | Jan.-Jun. 1944 | Jul.-Dec. 1944 | 1945 |
|---|---|---|---|---|---|
| Number of cases | 903 | 68 | 243 | 392 | 200 |
| Number of deaths | 247 | 25 | 84 | 98 | 40 |
| Per cent mortality | 27.3% | 36.7% | 34.9% | 25.0% | 20.0% |

Before dealing more fully with mortality, it is pertinent to recognize that the lower mortality rate for these patients in the latter half of 1944, and the year 1945, coincides with the era of penicillin. Without proof, nevertheless, it is considered that this reduction in mortality is a reflexion, more likely, of a greater knowledge and experience in dealing with the problem of the thoraco-abdominal wound as a whole, a greater appreciation of the thoracic implications and complications, a greater experience and facility of the individual surgeon and anesthetist in the operative treatment, and, lastly, a keener appreciation and attention to details of preoperative and postoperative care.

The gross mortality for the 903 cases with thoraco-abdominal wounds was

246, or 27.3 per cent. For 1943, the fatalities were 36.7 per cent for the first six months of 1944, 34.9 per cent, for the last half of that year, 25 per cent, and for 1945, 20 per cent. These mortality figures are for deaths in the first priority surgical hospitals, where the usual postoperative residence was from seven to ten days. Some cases remained in this hospital only a few days, while some stayed as long as 18 days.

It is impossible in the analysis of the mortality data to discover what effect the chest component of the wound had upon mortality except in the case of the wounds injuring the mediastinum. The mortality when this part of the chest was wounded was 50 per cent.

TABLE VI

RECORDED COMPLICATIONS IN 656 THORACO-ABDOMINAL WOUNDS—SURVIVAL CASES

| | No. of Cases |
|---|---|
| Atelectasis | 21 |
| Empyema | 17 |
| Empyema with bronchopleural fistula | 2 |
| Subphrenic abscess | 15 |
| Pneumonia | 12 |
| Abdominal wound disruption | 7 |
| Abdominal wound disruption, with evisceration | 3 |
| Bile empyema | 5 |
| Bile empyema, with bronchopleural fistula | 2 |
| Chest wound infection and breakdown | 8 |
| Intestinal obstruction | 5 |
| Persistent pleural effusion | 5 |
| Tension pneumothorax | 3 |
| Jaundice | 3 |
| Incomplete expansion of lung | 2 |
| Oliguria | 2 |
| Gastric hemorrhage | 2 |
| Chest wall and diaphragm breakdown | 1 |
| Psychotic state | 5 |
| Leg vein thrombosis | 2 |
| Hepatic abscess | 1 |
| Pelvic abscess | 1 |
| Pulmonary edema | 1 |
| Hemorrhage from thoracotomy wound | 1 |
| Pulmonary embolism | 1 |
| No complications recorded | 364 |
| No records | 165 |
| | 656 |

However, the most lethal part of the thoraco-abdominal wound was the abdominal portion. Roughly, the type of organ and number of organs wounded below the diaphragm was reflected in the mortality rate. Wounds involving five or more different organs were universally fatal.

The mortality rate of all abdominal wounds in the first-priority surgical hospitals as compared to the thoraco-abdominal wound is of interest. In abdominal wounds of all types there was a mortality rate of 24.1 per cent, in the thoraco-abdominal wound the rate was 27.3 per cent. This covers the entire period of 1943, 1944, and 1945 in the case records of the 2nd Auxiliary Surgical Group.

The cause of death and postoperative day on which death occurred were recorded in 234 out of 247 fatalities. Shock was given as the most frequent cause of death on the operating table, the day of operation, and the first postoperative day. Four (4) cases were recorded as having died on the operating table of hemorrhage. However, in the so-called shock death, blood loss was a contributory factor, as were overwhelming contamination and infection of the peritoneal and pleural cavities and retroperitoneal space, disturbance of cardiorespiratory physiology, and massive tissue destruction. In 15 cases renal

TABLE VII

MORTALITY-TIME POSTOPERATIVELY AND PRIMARY CAUSE OF DEATH

(*247 Deaths—13 Cases no Records*)

| Time and P.O. Day | Number of Deaths | Shock | Hemorrhage | "Renal Failure" Oliguria and Anuria | Atelectasis | Pneumonia | HT. Tamponade or Injury | Peritonitis | Missed Perforation | Peritonitis and Pleuritis | Pulmonary Emboli | Mismatched Blood | Blast | Mediastonitis | Fat Embolism | B-P Fistulae (Pressure pneumothorax) | Liver Deaths | Gas Infection | Disrupt. Diaphragm | Morphinism | Bronochoscopy | Meningitis | Liver abscess | Empyema |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| On operating table.... | 49 | 40 | 4 | | 3 | | 1 | | | | | | | | | | | | | | 1 | | | |
| Operative day..... | 76 | 59 | | | | | 2 | 6 | 2 | 2 | 1 | 1 | 2 | | | | | | | 1 | | | | |
| 1st P. O. day..... | 29 | 18 | | | 1 | 2 | | 2 | | 2 | 2 | | 1 | 1 | | | | | | | | | | |
| 2nd P. O. day..... | 28 | 12 | | | 1 | 7 | | 4 | | | 2 | | | | 1 | | | | | | | 1 | | |
| 3rd P. O. day..... | 12 | 1 | | 5 | 2 | | | 1 | | | 1 | | | | | 2 | | | | | | | | |
| 4th P. O. day..... | 9 | | | 4 | | 3 | | | | | | | | | | | 1 | 1 | | | | | | |
| 5th P. O. day..... | 7 | | | 4 | | 1 | | 2 | | | | | | | | | | | | | | | | |
| 6th P. O. day..... | 7 | | | | | 2 | | 1 | | | 1 | | | | | | | 1 | 1 | | | | | 1 |
| 7th P. O. day..... | 6 | | | 1 | | 2 | | 1 | | | 1 | | | | | | | | | | | | | 1 |
| 8th P. O. day..... | 3 | | | | | | | 1 | | | | | | | | | | | | | | | | 2 |
| 9th P. O. day..... | 3 | | | 1 | | | | | | | 1 | | | | | | | | | | | | 1 | |
| 10th P. O. day..... | 2 | | | | | | | 1 | | | 1 | | | | | | | | | | | | | |
| 11th P. O. day..... | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 12th P. O. day..... | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 13th P. O. day..... | 2 | | | | | | | 1 | | | | | | | | | | | | | | | | 1 |
| 14th P. O. day..... | 1 | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | 234 | 130 | 4 | 15 | 7 | 17 | 3 | 20 | 2 | 4 | 10 | 1 | 3 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 5 |

failure, as expressed in oliguria and anuria, was the cause of death most commonly encountered from the 3rd to the 5th postoperative. Peritonitis and pneumonia were the next most frequent cause of fatalities, respectively.

In nine cases, death was considered to have been due to the effect of an associated injury rather than as a result of the thoraco-abdominal wound. The rôle of the associated wound in the morbidity of these patients is an important factor. Lesions of the spinal cord, produced by the missile of the thoraco-abdominal wounds, have been considered as associated wounds. There were 95 severe, 129 moderate, and 161 mild associated wounds. The severe wounds included brain, cord, other chest, abdominal, fractured femur and amputations. The moderate group included fractures of long bones other than the femur, and multiple wounds of less serious nature than those of the severe category.

Flesh wounds and those involving fractures of the hand and foot are listed under mild wounds.

## CONCLUSIONS

1. Recognition of perforating wounds of the diaphragm in chest and abdominal casualties is of prime importance.

2. The value of correction of altered cardiorespiratory physiology in the preoperative period, of endotracheal anesthesia during the operation, and of reëxpansion of the lung at operation and postoperatively cannot be overestimated in the treatment of those patients.

3. The importance of early operation because of the abdominal wound, and of initial control of the thoracic pathology at operation upon the thoraco-abdominal wound is stressed.

4. The transdiaphragmatic procedure alone is a satisfactory method of approach in certain types of thoraco-abdominal wounds as demonstrated by the results of 362 procedures.

5. The reduction in the mortality of thoraco-abdominal wounds from 36.7 per cent, in 1943, to 20 per cent, in 1945, in the first-priority surgical hospital is the result of a fuller understanding of the problem of the thoraco-abdominal wound as a whole, of its thoracic implications in particular, of a wider experience of the individual surgeon and anesthetist, and of a keener appreciation of the essentials of preoperative and postoperative care. The rôle of penicillin cannot be estimated.

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# PERFORATED GASTRODUODENAL ULCERS

## A STUDY OF 166 CASES

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PERFORATION of intra-abdominal viscera is a serious condition. Peptic ulcer constitutes the most common cause of spontaneous perforation. Because of the high mortality associated with this condition, the present study was undertaken to determine what can be done to increase the rate of survival.

The data upon which this study is based was taken from the records of the King County Hospital, Seattle, Washington, and comprises the total number (166 cases) of perforated gastric and duodenal ulcers which came to this institution during a seven-year period from 1938 to 1944, inclusive. Many of the patients admitted to this hospital are in a poor state of nutrition; others are chronic alcoholics, old, and neglected. Most of the emergency surgery is done by the Resident Staff and junior members of the Attending Staff. Because of these factors the statistics cannot be compared with those in private practice, where the patients, as a rule, are in better physical condition. This study comprises only the intraperitoneal perforations of benign gastric, pyloric and duodenal ulcers. It does not contain perforation into other viscera such as the pancreas, gallbladder and bile ducts, nor does it include perforated malignant ulcers.

The etiologic factors are shown in Chart 1. They do not differ markedly from those already described by other authors.[8] Attention is called to the fact that 37, or 22.3 per cent, were acutely intoxicated upon arrival in the hospital. This makes the diagnosis and management of these patients difficult. They are uncoöperative and usually suffer from avitaminosis and hypoproteinemia. Two developed delirium tremens.

External trauma as an etiologic factor is interesting from the standpoint of workmen's compensation. One of us (M. N.) has had two instances of perforated duodenal ulcer which occurred while at work. The Department

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of Labor and Industries of the State of Washington accepted the responsibility for the surgical care and compensation of these patients. Corlette[8] studied the problem on the basis of the laws of physics and demonstrated that increase in intra-abdominal pressure cannot cause a strain in an ulcer; therefore, perforation from this cause cannot occur. There must be an increase in the hydrostatic pressure *within* the organ without increasing the intra-abdominal pressure, so as to have a difference in the two, before perforation can take place.

DeBakey,[8, 9] in a collected review, found that 5 to 33 per cent occurred while asleep. There are also reports of perforation following the administration of a barium meal.[8] Food indiscretion and overloading of the stomach undoubtedly play an important part. In about 50 per cent of our cases perforation occurred within three hours after eating a heavy meal. In our series no perforation resulted from administration of barium.

Bleeding was noted in 13 per cent. According to Einhorn,[10] and others,[8, 32] the blood supply of the duodenum accounts for this fact. Mayo[10] described the so-called anemic spot, which appears at times on the ventral wall of the first part of the duodenum when the intestine is stretched by traction on the pylorus. This is the most common site of duodenal ulcer, and is probably responsible for the axiom that a perforated ulcer seldom bleeds and a bleeding ulcer seldom perforates. Two patients had postsurgical hemorrhage. In most instances the blood loss was small and no patient in this group died.

Pain in the right lower quadrant was present in 20 per cent. Consequently, confusion in diagnosis arises, as one may suspect appendicitis or other lesions instead of the true pathologic condition. This is because the gastroduodenal contents spread downward in the right gutter. Rarely are acute appendicitis and perforated peptic ulcer present at the same time. Sanders[33] has reported such a case.

Shoulder radiation was, unfortunately, not recorded in 75 per cent of our cases. Of the 42 patients who were questioned in this regard, only seven had no pain. Raw[31] reported 60 per cent with radiation to the shoulder. This is an important diagnostic finding,[27] and the question should be asked of every patient. But as Cope[7] has pointed out, there are other conditions which give shoulder radiation at times, such as: subphrenic abscess, biliary tract disease, acute pancreatitis, appendicitis, ruptured ectopic pregnancy, diaphragmatic hernia, pulmonary conditions, and pericarditis. One must, therefore, evaluate this symptom in the light of the whole picture.

### PHYSICAL FINDINGS

Obliteration of liver dullness is of value. The patient is placed on the left side for four or five minutes. If there is an appreciable amount of air in the abdominal cavity, liver dullness will not be found.[28] Whereas this was recorded in only 17 instances, the test was positive in 11. Again, the evaluation of this finding must be made in the light of other features, as there are several conditions which will produce pneumoperitoneum.

Shock is not a common finding, as measured by blood pressure and pulse rate. Only 7.2 per cent exhibited evidence of this condition. Detection of early shock, however, can be made better by hematocrit determination,[24] but this laboratory procedure was not done. When shock is present the prognosis is serious, and every effort should be made to combat it before, during, and after surgery. We are of the opinion that Blalock's[5] studies offer the best explanation for the occurrence of shock. By injecting bile, pancreatic, stomach, and duodenal secretions intraperitoneally he found that any of these

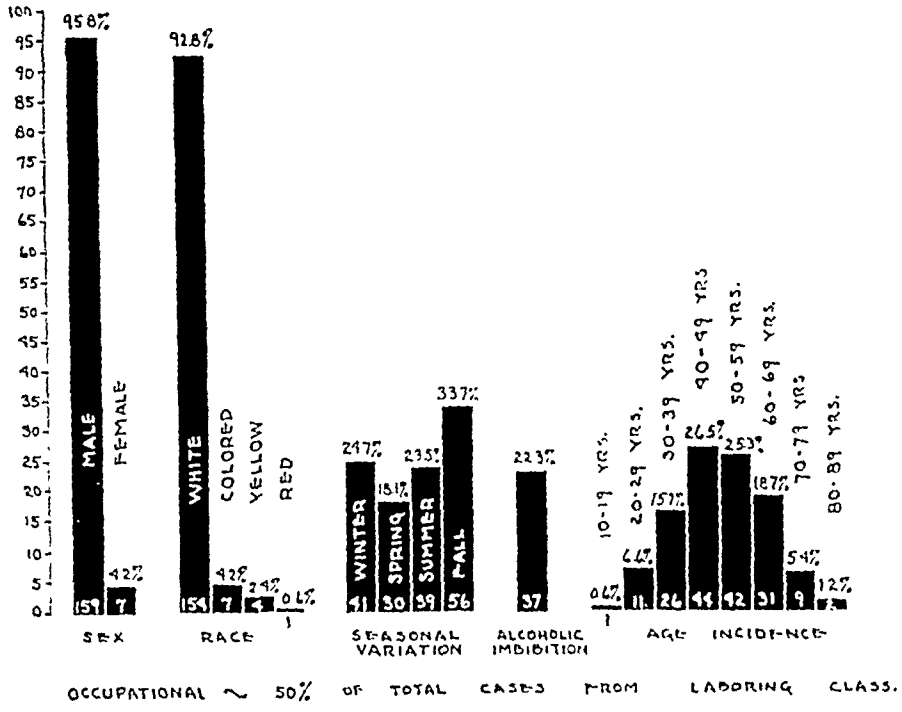



CHART 1.—Etiologic factors.

juices made the animals ill, with vomiting and increased pulse rate. When only one substance was injected, bile was found to be the most toxic. Infected pancreatic juice was next. But when bile and pancreatic juice were administered together there was decisive evidence of shock as measured by drop in blood pressure and cardiac output. Horrall,[18] and others,[22] have demonstrated the toxicity of bile when injected intraperitoneally. It is, therefore, believed that shock in perforated peptic ulcers is due largely to the action of bile and pancreatic juice, which is poured into the abdominal cavity. Hypo-albuminemia,[20] anemia, and dehydration also play important rôles.

*Laboratory Findings:* An important procedure is demonstration of pneumoperitoneum roentgenographically.[2, 8, 11] The patient is placed on the left side for at least 20 minutes, after which roentgenograms are taken of him in this position. One can better demonstrate free air intraperitoneally in this

manner than in the upright position, and a smaller amount is detectable by this maneuver. We have not tried DeBakey's[8] suggestion of injecting 20 to 30 cc. of air through a Levine tube placed in the stomach where no air could be found otherwise. Pneumoperitoneum must be interpreted in the light of the history and physical findings, as there are other conditions which will produce it.[28] Some of these are: recent celiotomy; peritoneoscopy; the Rubin test; ruptured appendicitis, especially when the perforation is near the cecum; perforated diverticulum or cancer of the intestinal tract.

The average leukocyte count was 12.422. In some instances there was no leukocytosis.

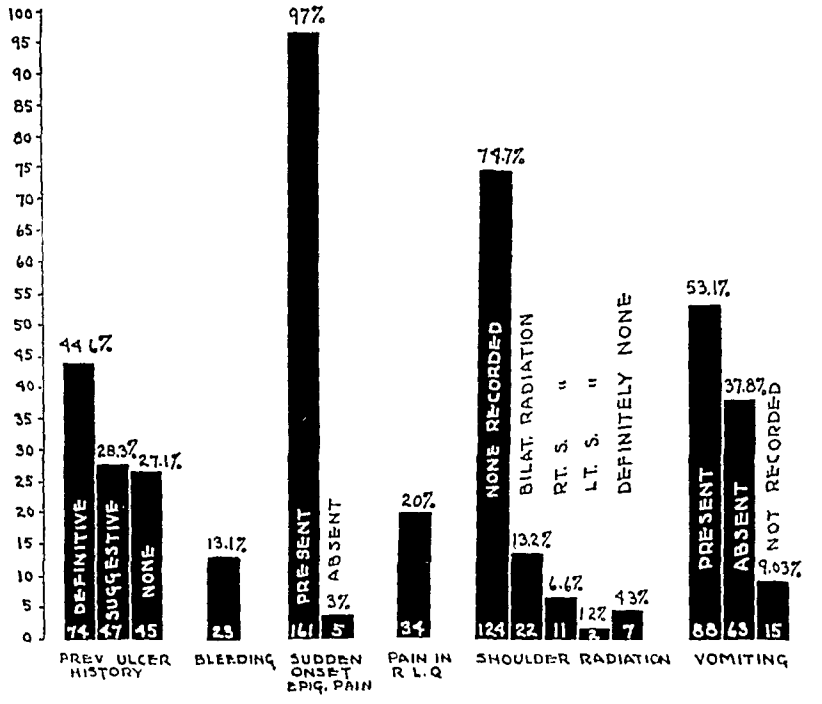



CHART 2.—Clinical history.

Ascorbic acid and serum protein levels were not determined in many instances, but a sufficient number was done to indicate the importance of these two factors in the treatment. Many patients suffering from peptic ulcer restrict the diet so that their biochemical balance is upset. If the hemoglobin is high,[24] it is an indication that shock is impending. Therefore, hematocrit determinations should be done, preferably in all cases and, certainly, in those where shock is suspected.

### DIAGNOSIS

In 11, or 6.6 per cent, the condition was not recognized until autopsy. Most of these patients were moribund upon arrival in the hospital. In 14, or 8.4 per cent, other conditions were suspected, although in most of these,

perforated peptic ulcer was included in the differential diagnosis. Appendicitis was the most common error. Acute pancreatitis was thought of in 11 instances but was ruled out by the serum amylase test.

### TREATMENT

*Medical:* Following the articles by Singer and Vaughan, in 1930[34] and 1932,[55] on *forme fruste* ulcers, one of our surgeons conceived the idea of treating selected patients with perforated peptic ulcer by suction and parenteral fluids. During the period included in this study, 17 patients were

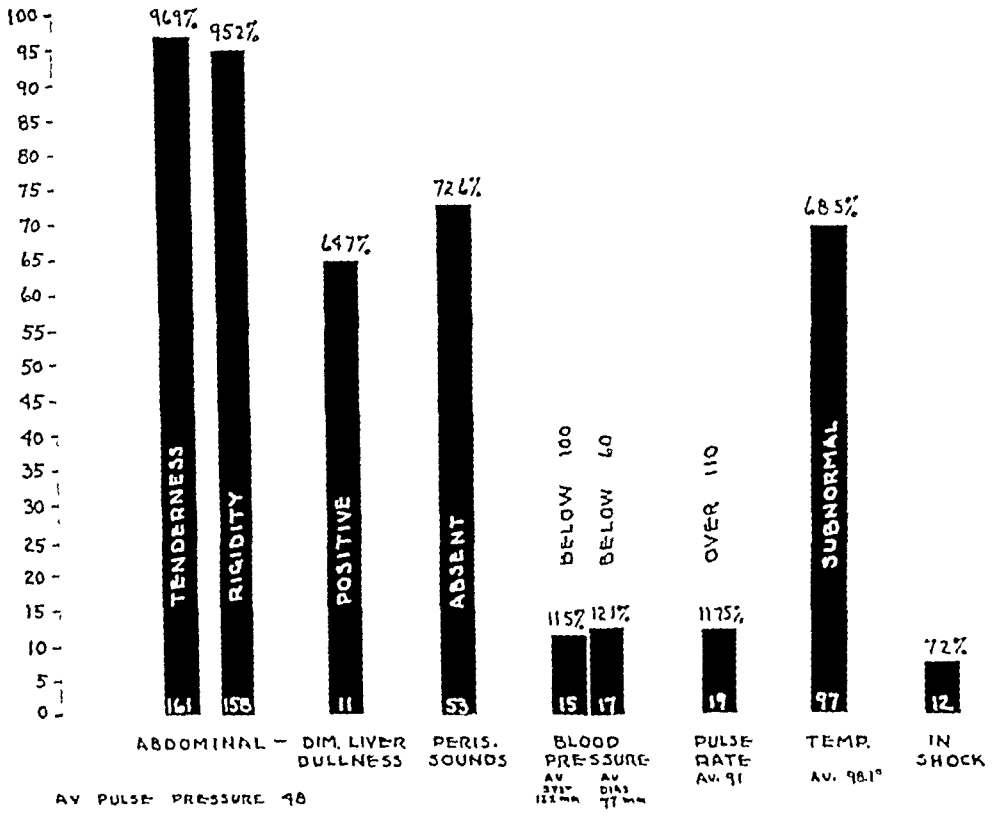



CHART 3.—Physical findings.

treated in this manner, of whom seven died, or a mortality rate of 41 per cent. While this series is too small from which to draw definite conclusions, it indicates that medical treatment is not the best procedure, even in selected cases. Consequently, this form of management has now been abandoned and is used only where operation is refused. One instance has been described[19] where a patient was treated 20 days by this method, but there still was no evidence of spontaneous closure of the ulcer. The patient was operated upon, but died 40 days later. However, this form of treatment[2] has demonstrated to us that suction is efficacious while the patient is being prepared for surgery by restoring biochemical and fluid balance. The period of hospitalization in this group averaged 20 days.

*Surgical:* Surgical treatment was instituted in 138 patients. It was found that an average of six and one-half hours elapsed from the time of perforation until admission to the hospital. Preparation for surgery took an additional two hours. In some instances the ulcer had perforated 24, 36, and even 72 hours before coming to the hospital. Attention is called to the promptness with which these patients were brought to surgery. As will be brought out later, we are of the opinion that in selected cases more time should be taken in the preparation of the patient before operation is performed.

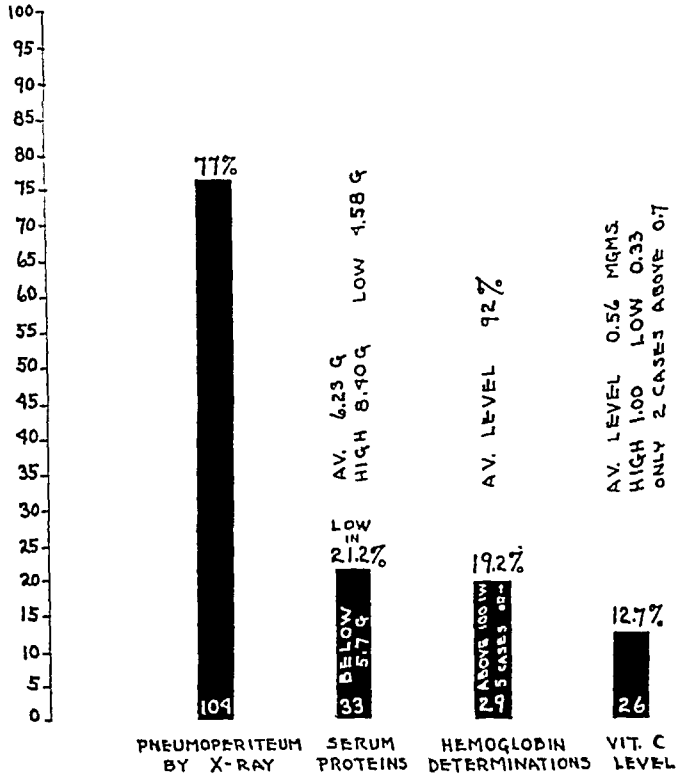



CHART 4.—Laboratory findings.

The type of incision is given in Table I. We feel that a transverse incision, about three inches in length, should be made; that the ulcer be closed, preferably with a living tag of omentum; that no sulfonamide drug be introduced into the abdomen or incision,[17, 26] nor drains inserted; and that as much of the stomach contents as possible be removed from the abdominal cavity. We have not practiced irrigation by the introduction of large amounts of saline. Although the number of procedures besides closing the ulcer were few, the data would indicate that such operations had better not be undertaken.[12-15] We make this statement despite good results reported by

surgeons who have performed partial gastrectomy,[4, 36] and gastro-enterostomy.[6, 23] in the presence of perforated peptic ulcers. A high percentage of these patients require no further operations after closure of the perforations.[9, 38] Table II summarizes the results in this regard. The average hospital stay was 16 days in this group.

Closure of the abdominal incision is important, as there were 24 wound infections and 14 wound dehiscences. It is our opinion that heavy catgut is contraindicated because of the exudate that accompanies the use of this material. Cotton, or preferably wire sutures (M. N.), have been found to be the most efficacious of all the suture materials used at present. Fine wire, No. 34 or 36, interrupted sutures produce no tissue reaction and seem to cause no after irritation. However, one must not rely on sutures alone to hold the incision together. Adequate serum protein and ascorbic acid levels must be maintained. It is our impression that sulfonamides introduced into the wound would hinder the healing process. We usually irrigate the incision after the peritoneum has been closed.

TABLE I

TYPE OF INCISION

| | No. of Cases | Wound Infection | Wound Disruption | Hematoma | Sulpha in Wound | |
|---|---|---|---|---|---|---|
| | | | | | Infection | None |
| 1. Right upper rectus | 106 | 16 | 13 | 0 | 7 | 10 |
| 2. Right subcostal | 10 | 2 | 0 | 2 | 1 | 0 |
| 3. Midline (upper) | 6 | 2 | 2 | 0 | 1 | 0 |
| 4. Transverse (above umbilicus | 3 | 0 | 0 | 0 | 1 | 0 |
| 5. All others | 6 | 2 | 0 | 0 | 0 | 0 |

TABLE II

REPAIR OF PERFORATION

| | No. of Cases | Deaths | Percentage Mortality |
|---|---|---|---|
| Types of ulcer repair: | | | |
| a. Simple plication, with or without omentum | 99 | 16 | 16.2 |
| b. Simple plication plus drainage | 19 | 6 | 31.5 |
| c. All others | 15 | 4 | 26.6 |

*Anesthesia:* Ether was administered in 93 instances and spinal in 19. Pentothal, nitrous oxide, and local infiltration were used in the remainder. Spinal anesthesia is desirable[13] if the patient's condition permits its use, as it gives good relaxation. It should not be used if the hemoglobin is less than ten grams per hundred cc. of blood. In poor risks, intercostal block and local infiltration of procaine or metycaine are valuable procedures. The average length of operation was 52 minutes.

*Complications:* The most important data regarding complications is given in Chart 5. If there is a rapid rise in temperature and pulse during the first three days following operation, pulmonary complications are to be looked for. If the patient is not doing well after the third day, intra-abdominal infections must be thought of, the most common being: peritonitis; pelvic

or subphrenic abscess, right or left. In our series, seven patients developed pelvic and, five, subdiaphragmatic abscesses. Reperforation occurred in two instances, therefore, this possibility must be kept in mind. Wound infection and dehiscence are serious complications, which have already been discussed.

*Mortality:* As will be seen from Chart 6, most of the deaths were due to peritonitis and pulmonary complications. However, some died from unrelated causes. Among them were two coronary occlusions and one ulcerative aortic endocarditis. The latter patient succumbed on the 37th postoperative day. It is believed that the primary disease had nothing to do with his demise. The over-all mortality was 27.7 per cent.

TABLE III

| Year | No. of Cases | Treatment | | Deaths | | Percentage Mortality | | Undiagnosed Proven at Autopsy |
|---|---|---|---|---|---|---|---|---|
| | | Surg. | Med. | Surg. | Med. | Surg. | Med. | |
| 1938 | 28 | 22 | 1 | 3 | 0 | 13.5 | 00.0 | 5 |
| 1939 | 25 | 23 | 2 | 10 | 0 | 43.5 | 00.0 | 0 |
| 1940 | 18 | 16 | 2 | 3 | 2 | 18.9 | 100.0 | 0 |
| 1941 | 19 | 12 | 4 | 5 | 0 | 41.7 | 00.0 | 3 |
| 1942 | 23 | 17 | 3 | 1 | 3 | 05.9 | 100.0 | 3 |
| 1943 | 29 | 25 | 4 | 2 | 2 | 08.0 | 50.0 | 0 |
| 1944 | 24 | 23 | 1 | 4 | 0 | 17.0 | 00.0 | 0 |
| 7 yrs. | 166 | 138 | 17 | 28 | 7 | 21.0 | 41.2 | 11 or 6.6 per cent. |

DISCUSSION.—The over-all mortality in our group is high, but not greater than recorded[16] in collected reports,[8, 9] or in large series from similar institutions,[37] such as the Cook County Hospital.[21] Reports on 30 to 90 cases[9, 12, 15, 25] have been made with lower mortality, but these have usually been private patients treated by one surgeon. It is interesting to note that Graham, in recording 51 duodenal perforations,[12] had a mortality of 1.9 per cent. When this series was extended to 106[13] cases, the death rate had risen to 6 per cent.

Most authors emphasize the importance of early operation. We agree with this view. But how are we to manage those patients who do not come to the hospital until the optimum time for operation has passed, or who are in a poor physical state? In reviewing this series, it was found that some patients died within a few hours after operation had been performed. One died on the way to the operating room. Two expired under anesthesia, before surgery could be instituted. As Graham[12] has pointed out, the old adage that the sun should neither set nor rise on a perforated ulcer is no longer valid. If a patient is in such a condition that he succumbs on the way to the operating theater, or dies a short time after surgery has been performed, it would seem prudent not to operate upon him until his condition has been improved. This can usually be accomplished by suction, the introduction of fluids, plasma, blood transfusions and vitamins — in short, restoring the biochemical and fluid balance. The patient should have a reasonable chance to survive the

operation before surgery is instituted. At present, this can be measured to a fair degree of accuracy by hematocrit, plasma protein determinations, ascorbic acid levels, as well as the general appearance of the patient. Peritonitis, although an important lethal factor, need not be feared as much now that we have the sulfonamide drugs and penicillin. These agents should be administered while the patient is being prepared for surgery. Again, medical management of these patients has indicated that by intragastric suction very little gastroduodenal content is spilled into the peritoneal cavity. Actual spontaneous sealing-off of the ulcer might occur.[37] Since it has been demonstrated

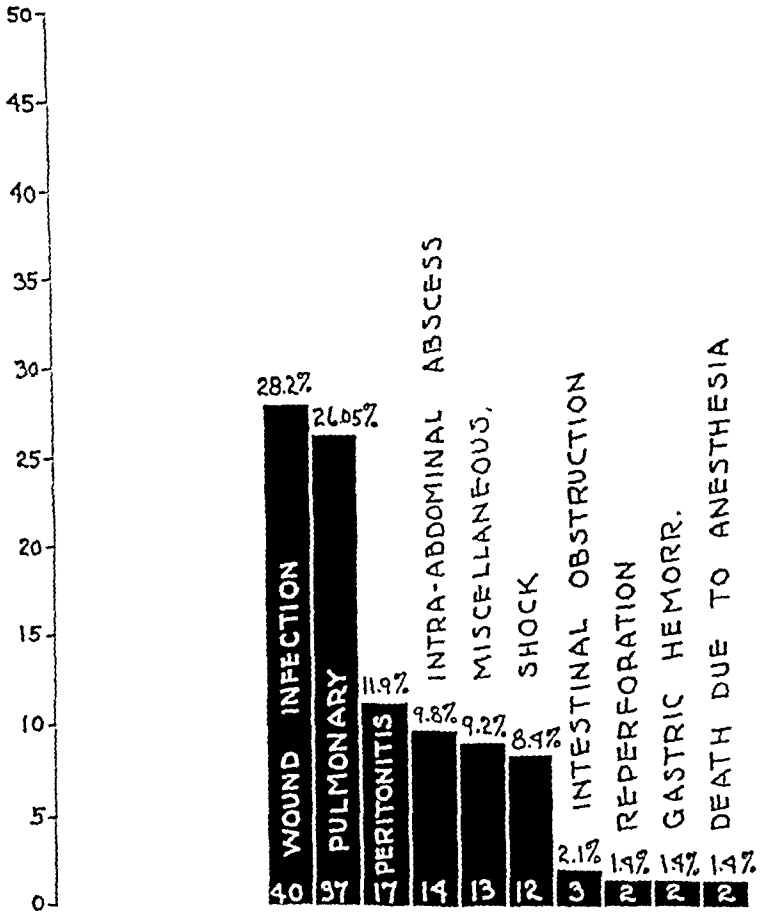



CHART 5.—Complications.

that this is a chemical rather than a bacterial peritonitis,[1, 3, 29, 30] one can take time to prepare the patient properly[13] before surgery is instituted.

When operation has been decided upon, careful consideration should be given to the anesthesia. The agent best suited to the individual patient must be used. Instead of having anybody "pour the ether," a competent anesthetist should be in charge at every operation. Preoperative medication must be administered with caution. It is the impression of one of us (H. B. O.) that two patients died because of administration of excessive doses of morphine.

The following outline for the general management of perforated peptic ulcer is presented:

1. Obtain the clinical history and make physical examination. Evaluate the patient's general condition.

2. Introduce gastric suction.

3. Place the patient on his left side for the purpose of demonstrating obliteration of liver dullness and preparatory to taking a roentgenogram to show pneumoperitoneum.

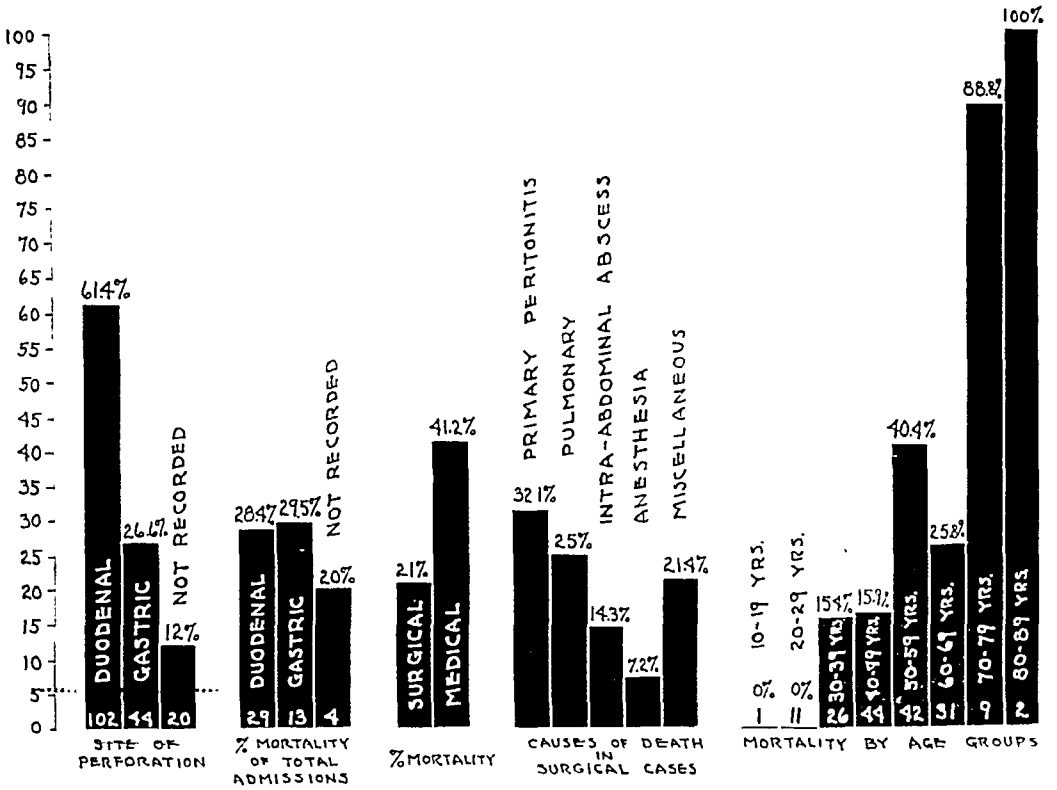



CHART 6.—Mortality statistics.

4. Administer an opiate sufficient to keep the patient fairly comfortable, but excessive amounts must definitely be avoided.

5. Laboratory work should consist of the following: Hematocrit determination, complete blood count and urinalysis, serum protein determination, and albumin-globulin ratio. It is not necessary to determine the blood ascorbic acid level if the patient is given at least 500 mg. of this vitamin before surgery.

6. Administer intravenous fluids of 5 per cent glucose and saline, as well as plasma or blood transfusions, depending upon the hematocrit reading and plasma findings. If possible, delay operative intervention until hypoproteinemia and anemia have been largely corrected. Spinal anesthesia is

preferred because it gives good relaxation, which is conducive to the least trauma in performing the operation. A trained anesthetist should be responsible for this important part of the operation.

7. Begin penicillin and sulfonamide drugs therapy if indicated.

8. Make a short incision directly over the distal end of the stomach and duodenum. If the diagnosis is clear, a transverse incision should be made. But if one suspects another lesion, a vertical incision is better, as this can be extended. Introduce methylene blue through the Levine tube if the perforation is not readily found.

9. Limit the surgical procedure to closing the perforation, preferably with a living tag of omentum. If this is not possible, a piece of omentum may be excised and used as a patch. Use only three or four sutures, inserted widely, according to the method of Graham.

10. Postoperative Treatment:

a. Continue gastric suction;

b. Administer fluids intravenously from 2,500 to 3,500 cc. daily. Add amino-acids and give blood transfusions and plasma if indicated:

c. Give ascorbic acid from 300 to 500 mg. daily.

d. Encourage the patient to move freely in bed, and cough if he has mucus.

e. Oxygen should be given before, during, and after surgery as indicated;

f. Check serum protein levels.

g. Continue penicillin or sulfonamide therapy if indicated.

## SUMMARY

1. A study of 166 instances of perforated gastric and duodenal ulcers, collected from the records of the King County Hospital, Seattle, Washington, over a seven-year period is presented.

2. An outline of management is presented which, it is hoped, will reduce the surgical mortality of perforated peptic ulcer.

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# CONGENITAL STENOSIS OF SMALL INTESTINE: WITH RETENTION OF NONPENETRATING FOREIGN BODIES

## REPORT OF TWO CASES

McCHORD WILLIAMS, M.D.*

CHARLOTTE, N. C.

CONGENITAL STENOSIS of the small intestine is an extremely rare condition. In 1941, only 22 cases of stenosis of the intestinal tract had been seen at the Children's Hospital, Boston.[1] According to Loitman,[2] stenosis is more uncommon than atresia of the intestine, though, according to Hancock,[3] the reverse is true. Atresias occur once in 20,000 births, according to Webb and Wangensteen.[4] The duodenum is the most common site of stenosis, the ileum being involved next in frequency.

A search of the literature revealed only one case of retention of a foreign body as a result of congenital stenosis. This case was described briefly by Ladd and Gross,[1] under the discussion of foreign bodies in the intestinal tract and it served as a basis for an indication for operative intervention in cases where foreign bodies do not progress down the intestinal tract. Because the case had not been fully described it is being included as Case 1, through the kind permission of Dr. Robert E. Gross.

### CASE REPORTS

**Case 1.**—A. D., a five-year-old child, was admitted to the Children's Hospital, Boston, February 23, 1927, because of persistent vomiting. The patient had been well until six months before admission, when he began to lose weight. Three weeks before admission he began to vomit intermittently. Vomiting became more frequent, and the child complained of severe cramp-like abdominal pains. These pains lasted five to six minutes and were relieved by abdominal massage and vomiting. The child's bowels had been loose during the five weeks prior to admission.

The family and past history were noncontributory.

Physical examination revealed a fairly well-developed and well-nourished child, slightly dehydrated. The abdomen was soft and tympmanitic. There was no spasm or rigidity. A vaguely outlined mass was palpated descending in the midline to the left of the costal margin for a distance of about 5 cm. Laboratory studies were within normal limits.

A roentgenogram of the abdomen was taken on the day following admission. This revealed in the region of the cecum a foreign body which had the appearance of a small coin. Thereafter a series of roentgenograms were taken until March 20, at which time no progress in the passage of the foreign body was noted. On that date the patient's abdomen became distended and he vomited repeatedly.

*Operation.*—March 21, 1927: Twenty centimeters below the ligament of Treitz a constriction was found in the jejunum which held the foreign material in place. The jejunum was dilated above the point of obstruction. The foreign bodies were displaced upward, an enterotomy was done, and a penny, a split button, and a nonabsorbent lozenge were removed. The stenotic area was then resected and side-to-side anastomosis done.

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Pathologic examination revealed the stenotic area to be 2.5 cm. in circumference when opened. There was some hypertrophy of the muscular wall. No inflammatory reaction was noted which might have caused the stenosis.

The patient's postoperative course was uneventful; was discharged on April 4, 1927.

**Case 2.**—F. B., a 20-months-old male infant was admitted to Walter Reed General Hospital, May 30, 1945, because of repeated crampy abdominal pains and vomiting of 24 hours duration.

The past history revealed that the patient was delivered normally at full term. Soon after birth he had a profuse hemorrhage by rectum. The bleeding was treated with transfusions and parenteral fluids. The infant developed abdominal distention, and intestinal obstruction was suspected. After hospitalization for about three weeks the patient improved. At the age of three monhs, however, his liver was palpated 4 cm. below the costal margin, he was slightly jaundiced, and there was a rachitic rosary present. Diagnoses by the attending pediatrician included mild rickets, anemia, gastro-intestinal anomaly, and vitamin deficiency. The patient improved under treatment, though his abdomen became distended intermittently.

At the age of 17 months the infant developed diarrhea and was treated in the Outpatient Department of Walter Reed Hospital. At that time his abdomen was distended. A gastro-intestinal series, taken August 31, 1944, revealed a foreign body, a metallic nut, measuring about one centimeter in diameter, in the abdomen. There was no evidence of intestinal obstruction or of megacolon. There was a slight hypochromic anemia, and a blood lead determination was reported as being within normal limits. It was felt that the foreign body would pass, and no further attention was paid to it. *Lamblia intestinalis* were found in the stools, and the patient was treated with atabrine, resulting in improvement. However, his abdomen became distended intermittently and only small amounts of food could be taken at each feeding.

Physical examination on admission to the hospital because of vomiting revealed a fairly well-nourished infant of 26 months, with a soft, distended abdomen and visible peristalsis. A roentgenogram of the abdomen revealed the metallic foreign body still present in the abdomen after an interval of nine months. There was no characteristic picture of intestinal obstruction. Following one night's observation, during which time parenteral fluids were administered, a repeat roentgenogram of the abdomen revealed a single dilated loop of small intestine.

*Operation.*—May 31, 1945: On opening the abdomen many dilated bluish loops of small intestine were encountered. Exploration of the abdomen revealed a smooth, firm mass of tissue, measuring 5 to 6 cm. in diameter, in the mesentery of the involved intestine, with many adhesions. One band was constricting the mesentery of a section of about 50 cm. of ileum as well as the lumen of the ends of the loop. This adhesion and several others were divided between clamps and ligated. Further exploration revealed a narrow portion of ileum distal to the strangulated area, which measured about 1.5 cm. in diameter. The wall was of normal thickness and showed no evidence of inflammation. The colon was completely collapsed. After release of the adhesions gas was seen passing into the colon. No evidence of the foreign body was noted, unless it could have been contained in the mass in the mesentery. The operation was interrupted on two occasions because of severe shock. The patient's condition improved during the administration of a transfusion through the jugular vein. After release of the adhesive band, the color of the involved ileum improved remarkably. After reduction of the intestines, the wound was closed in layers with interrupted silk. Convalescence was uncomplicated and the patient was discharged from the hospital on June 8, 1945.

Following discharge from the hospital the patient did well, though the abdomen remained distended, and he did not gain weight.

The child was readmitted to the hospital, September 24, 1945, for relief of partial

intestinal obstruction. He was prepared for operation with three grams of sulfasuxidine by mouth, daily, for four days, and a transfusion of 250 cc. of citrated blood. A roentgenogram of the abdomen revealed the same foreign body in the right lower quadrant of the abdomen.

*Second Operation.*—September 29, 1945: The small intestine was found to be widely dilated. Exploration revealed no mass in the mesentery. Numerous adhesions were divided, and the point of stenosis was located at a site about 30 cm. above the ileocecal valve. Its appearance is shown in Figure 1A. Above the area of stenosis the ileum was dilated to about four times its normal diameter, and below it the ileum and colon were collapsed. The foreign body was palpated, free in the lumen of the

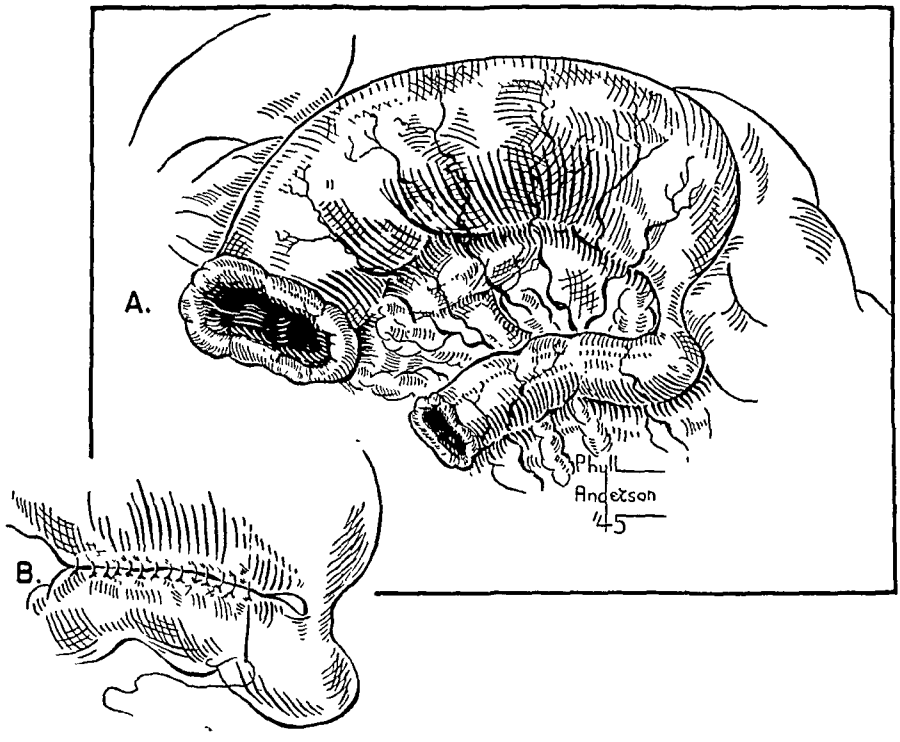



FIG. 1.—Case 2: (A) Area of stenosis of ileum. (B) Entero-enterostomy.

ileum, about 25 cm. above the area of stenosis. An entero-enterostomy was then performed, side-to-side, between areas just proximal and distal to the area of stenosis, as shown in Figure 1B. On completion of this procedure two fingers could be passed easily through the stoma, and it was felt that the foreign body would pass spontaneously through the opening. Since the child's condition was not particularly good, prolonging the procedure for removal of the foreign body was considered inadvisable, and the abdomen was closed.

The postoperative course was uneventful. Wangensteen suction was discontinued after four days, and the patient began to take fluids without vomiting. All stools were examined; the foreign body was not found. A bulky diet was given, and on the ninth postoperative day a gastro-intestinal series was made. This revealed the foreign body low in the right lower quadrant. Its position was not changed by passage of the barium. The patient was discharged from the hospital October 14, 1945. Following discharge the patient gained weight and the distention completely subsided.

On October 28, 1945, one month after the second operation, a roentgenogram of the abdomen revealed the metallic nut still present. The patient was readmitted to the hospital, and, on the following day, the third operation was performed through a small incision. The entero-enterostomy was found to be widely patent, admitting two fingers with ease. The foreign body was found lying in the stenotic area. It was displaced upward, removed, and the ileum was closed. The postoperative course was uneventful, and the patient was discharged November 3, 1945.

DISCUSSION.—In neither of these cases was an hyperchromic anemia noted, such as has been described by Meulengracht,[6] Deutsch,[7] and others, occurring with benign stenosis of small intestine.

In Case 2, the profuse gastro-intestinal hemorrhage, which occurred soon after birth, may have been the result of rupture of a congenital diaphragm occluding the intestine, as described by Loitman,[2] Ladd and Gross,[1] and others.

According to Ladd and Gross,[1] entero-enterostomy is the procedure of choice in the treatment of congenital stenosis of small intestine. In Case 2 it is apparent that the foreign body should have been removed at the time of entero-enterostomy.

It is interesting to note that the nonpenetrating foreign body remained free in the lumen of the intestine for 14 months. The strangulation obstruction was related, perhaps, to the congenital stenosis by lengthening of the mesentery in the chronically distended intestine, and by an inflammatory reaction with formation of adhesions secondary to distention and its attendant congestion of circulation. The mesenteric mass, which disappeared between the first and second operations, must have been enlarged lymph nodes due to congestion.

## SUMMARY

1. Two cases of congenital stenosis of small intestine, with retention of nonpenetrating foreign bodies, are presented. No other cases of this description have been found in the literature.
2. As has been pointed out by Ladd and Gross,[1] children who have ingested blunt foreign bodies which have entered the stomach should be followed by repeated roentgenograms of the abdomen until the foreign material has passed. In case of undue delay, abdominal exploration should be performed.
3. The diagnosis of congenital stenosis of small intestine should be considered in infants and small children who have been troubled with recurrent abdominal distention since birth.

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# FAMILIAL DIVERTICULOSIS OF THE COLON

## REPORT OF SEVEN CASES IN ONE FAMILY OF NINE PERSONS

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DIVERTICULOSIS OF THE COLON is a condition that has been recognized by anatomists for centuries. Only during the past thirty years, however, has the study of the gastro-intestinal tract by means of contrast radiograms called to our attention the relative frequency of this malady. The true importance of diverticulosis of the colon as a cause of intestinal obstruction, peritoneal infection and chronic colitis is now well recognized. There is also general agreement as to the best methods of treatment and these are well known. In the question of etiology remains the greatest diversity of opinion.

Diverticulosis of the colon in universally accepted as being an herniation of the mucosa and submucosa of the intestine through a defect in its circular muscle layer. There are several schools of thought on why this phenomenon occurs. One group of investigators believes that diverticula of the colon may develop essentially as the result of a combination of physical forces. This usually consists of a weakening or spreading of the circular muscle layer of the bowel at the points of entrance of its blood vessels by an increase of intracolic pressure due to constipation, muscular spasm, or other causes. This view is shared by Ceballos,[1] Dixon,[2] and Edwards.[3] A different opinion is expressed by Fansler,[4] who believes that degenerative changes occur in the muscle layer near middle age which makes damage by traumatization of hard stools and gas distention more easy. He does not believe that diverticula develop at the points of vascular penetration. Wierda[5] believes that diet may be a factor in etiology since he found diverticulosis of the colon in three rats fed on a high fat diet. Then, there is the belief that before a diverticulum can be formed there must exist a congenital anatomic deficiency in the wall of the colon which will act as a starting point. This view is held by Poate,[6] who has noted the presence of diverticulosis in young people before the age at which degenerative changes take place. Likewise, Erdmann[7] has reported a case of diverticulosis of the colon in a boy 11 years old, and he states that he has knowledge of other cases occurring in children, and, thus, believes that there is a congenital factor in etiology. Badia[8] has reported a case of diverticulosis of the colon in a 14-year-old boy, which he feels must be due to a congenital weakness in the muscular coat. Cave[9] believes that an inherent weakness in the muscle fibers is an underlying cause of diverticulosis. Bearse[10] states that the most likely causes of diverticulosis in young adults are probably structural defects in the colon which may be congenital. He further states that a tendency to



FIG. 1



FIG. 2

FIG. 1.—Case 1: Ascending colon and hepatic flexure with multiple diverticula.
FIG. 2.—Case 2: A portion of the descending colon with many large herniations.



FIG. 3



FIG. 4

FIG. 3.—Case 3: Diverticula of the sigmoid colon.
FIG. 4.—Case 4: Region of the splenic flexure of the colon with diverticulosis.

diverticulous formation may be inherited, and cites one of his cases whose father also had diverticulosis of the large intestine.

If diverticulosis of the colon actually does develop upon preëxisting congenital defects in the structure of the bowel it would follow that such defects could be a familial trait, and, thus, several cases of diverticulosis might develop in members of one family. It is the purpose of this paper to report just such an occurrence.



FIG. 5

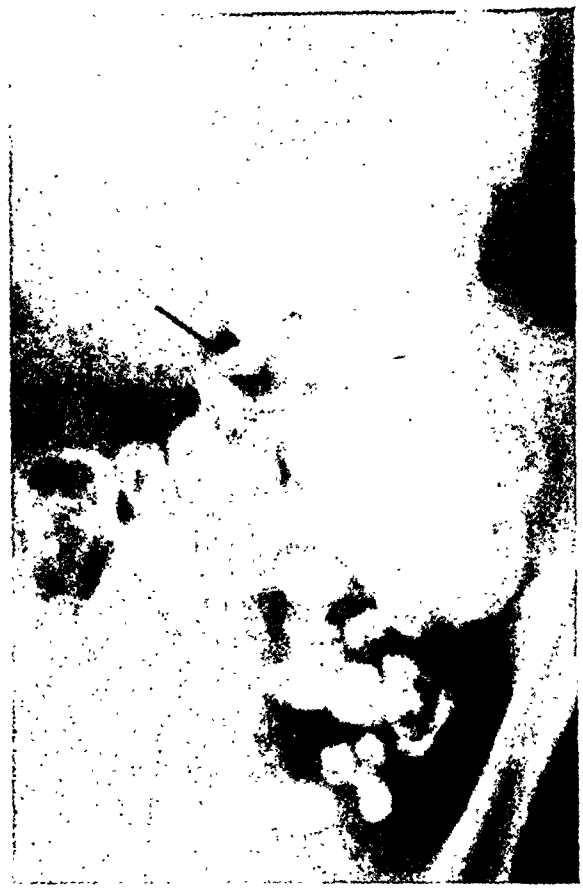


FIG. 6

FIG. 5.—Case 5: Part of the descending colon with diverticula.
FIG. 6.—Case 6: Diverticulosis of the colon at the splenic flexure.

Herewith is a report of the presence of diverticulosis of the colon in seven full brothers of one white family that consists of seven males and two females. After two members of this group had developed symptoms referable to the colon and each was found to have diverticulosis involving the entire large bowel, a study was made of the remaining brothers and sisters. Each of these was requested to fill out a comprehensive history form pertaining to the gastro-intestinal tract. Radiograms of the colon were obtained in each case after the administration of a contrast enema or after the ingestion of contrast media. These individuals reside in widely separated parts of the Pacific coast area, and the radiograms were made in different

laboratories and under varying conditions. All of the original radiograms were studied by Walter L. Stilson, M.D., Radiologist, of Los Angeles, California.

## CASE REPORTS

**Case 1.**—A. D. S., a Washington physician, age 67, height 66 inches, weight 220 pounds, was in active practice when symptoms of acute peritonitis developed in 1941. Celiotomy revealed the presence of an abscess in the lower left abdominal quadrant, which proved to be secondary to a perforated diverticulum of the sigmoid flexure of the



FIG 7

FIG. 7.—Case 7: Diverticula of the sigmoid colon.

colon. Drainage was accomplished, and recovery followed. Contrast radiograms demonstrated the presence of multiple diverticula of the entire colon. Figure 1 shows the ascending colon and hepatic flexure in this case with innumerable diverticula filled with the contrast media.

**Case 2.**—J. A. S., a California salesman, age 64, height 71 inches, weight 225 pounds, suffered vague digestive disturbances for many years. The main complaints were indigestion, flatulence and diarrhea associated with pain in the lower left abdominal quadrant. Radiologic studies of the colon revealed the presence of over 50

diverticula, with involvement of the entire large bowel. Figure 2 shows a part of this man's descending colon which contains many very large herniations. Almost complete relief of symptoms was obtained through medical treatment.

**Case 3.**—H. A. S., a central California poultryman, age 70, height 69 inches, weight 165 pounds, was studied after two of his brothers (Cases 1 and 2) were found to have diverticulosis. A contrast enema showed many diverticula of the descending colon. Figure 3 demonstrates one large and several small diverticula in the sigmoid region of this man's large bowel. There was no history of constipation, flatulence, or other evidence of the definite pathology that existed.

**Case 4.**—D. A. S., an Idaho farmer, age 68, height 62 inches, weight 132 pounds, was studied during the routine family survey. There was no history of constipation, gas formation, or other gastro-intestinal disturbance. The contrast enema showed the presence of diverticulosis of the descending colon. Figure 4, taken from the region of his splenic flexure, shows several of the diverticula filled with barium mixture.

**Case 5.**—J. H. S., a retired California railroad brakeman, age 55, height 72 inches, weight 227 pounds, experienced severe indigestion in 1938. A diagnosis of peptic ulcer was made and a diet was prescribed, with successful results. There has been no recurrence of symptoms. No history of constipation was obtained. A routine radiogram proved the presence of diverticulosis of this man's descending colon, a part of which is seen in Figure 5.

**Case 6.**—C. R. S., a California lumber mill employe, age 52, height 74 inches, weight 160 pounds, had enjoyed good health with no history of constipation, flatulence, or other disorder of the gastro-intestinal tract. Figure 6 shows his colon at the splenic flexure, with several diverticula in evidence.

**Case 7.**—E. E. S., a central California lumber executive, age 49, height 71 inches, weight 195 pounds, gave no history of intestinal abnormality other than hemorrhoids. The routine contrast enema revealed many diverticula of his descending colon. Figure 7 shows several of the herniations in the sigmoid region.

In the two female members of the family no evidence of diverticulosis could be found, either by careful history or by radiologic examination. One sister was completely bedfast because of advanced cardiac decompensation and radiograms made with a small portable machine in the home were not entirely satisfactory.

COMMENT: That seven brothers in one family of nine persons could be afflicted with diverticulosis of the colon may of course be a coincidence, but it is not likely. This series of seven cases represents 100 per cent of the male members and 78 per cent of the entire family that was studied. These figures are interesting when compared to the incidence of diverticulosis of the colon in the general adult white population which is estimated to be between 2 per cent and 5 per cent. In the group of cases here presented there is a wide variation in the size and weight of these men as well as in their places of abode, occupations, social status, and in their habits of living. There is no apparent common factor of etiology other than ancestry.

From the evidence which has been presented it is apparent that heredity cannot be disregarded as an etiologic factor in the formation of diverticula of the colon. It is logical to believe that there must be a congenital anatomic defect in existence before the mucosa and submucosa can herniate through

the muscle layer of the intestine; even as a congenital defect in the abdominal wall is usually necessary for the formation of an inguinal hernia.

## SUMMARY AND CONCLUSION

1. Diverticula of the colon are herniations of the mucosa and submucosa through defects in the muscle layer of the bowel, usually at the points of entrance of blood vessels.

2. Prevailing beliefs as to why this occurs include: (a) physical forces; (b) degeneration of the muscle layer incident to age and trauma; (c) diet; and (d) the presence of congenital defects in the bowel wall.

3. Reports are presented of seven cases of diverticulosis of the colon in one family of nine persons.

4. The conclusion is reached that heredity should be included as a major causative factor in the etiology of diverticulosis of the colon.

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# CARCINOMA OF MECKEL'S DIVERTICULUM

CASE REPORT

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CARCINOMA OF MECKEL'S DIVERTICULUM has been reported at infrequent intervals and the total number to the present time is small enough to make an additional case of interest. It is rare enough that no one individual has reported more than one case. A few isolated cases of tumors of this congenital anomaly, other than carcinoma, appear in the literature.

For the origin of the diverticulum we must consider the embryologic development of the fetus. Towards the end of the second week of embryonic life there develops a spherical sac with a wide opening into the intestine. This is known as the yolk sac, and during the third week of fetal life it becomes constricted-off from the embryo, maintaining one connection known as the yolk stalk. This stalk is also known as the vitelline or omphalomesenteric duct. Complete closure of the stalk usually occurs around the fifth week of intra-uterine life. Incomplete obliteration of the stalk explains the formations of the congenital anomaly, Meckel's diverticulum. According to Nygaard and Walters, Meckel's diverticulum is found in about 2 per cent of all adults. It is usually situated in the ileum at a distance of 25 to 100 centimeters from the iliocecal valve on the antimesenteric border. The length of the diverticulum, as well as the size of the lumen, may vary considerably. Ordinarily, the end is free but at times it may be adherent to the abdominal wall, the adjacent viscera or the mesentery, and at times this may be the cause of strangulation of the intestines.

Histologically, it usually contains all the cellular elements which make up the intestinal wall of the ileum. This generally consists of four coats, although, according to Reiser it usually lacks the circular musculature. The mucosa resembles ileum and includes villi and intestinal glands. However, in about 15 per cent it may have mucosa of the gastric type, generally of the fundic variety and in rare instances it may resemble mucosa of the colon and even include pancreatic tissue. Thus, in addition to the tumors arising from the normal cellular elements others arising from foreign or aberrant tissue elements, may be encountered.

In 1942, Albright and Sprague gathered six previously reported cases of carcinoma occurring in Meckel's diverticulum, and to this collection they made an addition of one case of their own. Of these seven cases, five were identified as adenocarcinoma and two as medullary carcinoma. Included in those classified as adenocarcinoma is one reported by Gray and Kernohan which was shown to have its origin in gastric mucosa within the diverticulum. All of these specimens were obtained from surgical cases in which removal of the diverticulum, portions of small intestine and metastatic areas were accomplished. In all but one of these above cases the

patient survived the operation. In the case of Wisely the patient died three days postoperative, and an autopsy performed showed no metastasis. I can find no other record of follow-up. The immediate results in all were very good.

In addition to the above there has been one other case of carcinoma of Meckel's diverticulum which was reported by Weir in 1937. This was not




FIG 1.—Gross specimen showing diverticulum (X) unopened

included in the seven reported by Albright and Sprague. In this instance an autopsy was also performed and extensive metastases were found studding the peritoneal surfaces, in the omentum and liver. It had also infiltrated the mucosa of the jejunum. Histologically, it was a highly anaplastic new growth with abortive attempts at the formation of glands. The addition of this case, therefore, brings the total number of adenocarcinomas previously reported to six.

In addition to the carcinomas there have been several other types of tumors, benign and malignant reported as arising in Meckel's diverticulum Nygaard and Walters found 14 cases of sarcoma in a total of 20 cases of malignant tumors. Weir, in his review, also mentions five cases of carcinomoid tumor. Thus, the various types found are more or less equally divided.

Clinically, it is very difficult to make a diagnosis of tumor of Meckel's diverticulum before operation or necropsy. The most common presenting symptoms would lead to the impression of an acute pathologic lesion in the abdomen. The tumor itself may or may not be palpable, although the symptoms do not depend on the size of the tumor. Secondary complications such as intestinal bleeding, intussusception, obstruction or perforation, with either local or diffuse peritonitis, may be responsible for calling attention to the condition. In six cases the lesion was demonstrated roentgenologically.



FIG. 2.—Gross specimen showing diverticulum (X) opened with tumor filling the lumen.

Most of the above symptoms may also be caused by a nonmalignant lesion of the diverticulum. It may give rise to obstruction, intussusception or ulceration without containing a tumor mass. These benign inflammatory lesions greatly outnumber the malignant lesions. They present the same group of symptoms and in some cases a mass may also be felt.

**Case Report.**—The patient, W. R., a 55-year-old colored male, was admitted to the Veterans Administration Facility at Hines, Illinois, June 12, 1945 at 8:00 P.M., for the treatment of acute appendicitis. His past and military history were irrelevant. He did not recall any previous illness of importance and had had no operations. There

was no history of gastro-intestinal or genito-urinary trouble. On admission, he stated that he had pain in his stomach about three weeks before. He called his physician who told him he had appendicitis and cystitis. At this time he reported to the Out-patient Department of this hospital, where a diagnosis of appendicitis, subsiding, was made and he was placed under the care of his own physician with instructions to return if he had a recurrence.

The patient returned to his work and was apparently well until 6:00 P.M., June 12, 1945. At this time, he developed an acute, sharp pain in his stomach and he was



FIG. 3.—Photomicrograph showing tumor cells tending to form gland-like structures. (x 300)

given first-aid by the doctor at the post office where the patient was an employee. He was brought to this hospital immediately by ambulance.

On his arrival he was seen by the surgical consultant. Examination at this time showed his abdomen to be slightly distended but not rigid. There was tenderness over the entire lower abdomen but it was more marked on the right side. Rebound tenderness was also elicited. There were no palpable masses. Laboratory studies showed W.B.C. 19,200, with 90 per cent polymorphonuclears and 10 per cent lymphocytes; R.B.C. 4,600,000, with 90 per cent hemoglobin. The urinalysis was negative.

*Operation.*—Under spinal anesthesia, the abdomen was opened, and about two ounces of seropurulent material escaped. The mesentery of the appendix was clamped but on exposure the appendix was apparently normal. However, it was removed. Exploration then revealed a tumor mass of the ileum which was adherent to the anterior parietal wall. This mass was freed by blunt dissection and brought out through the operative incision. It was approximately 18 inches from the cecum and about 7 cm. in diameter.

The surrounding tissue and intestine were apparently normal. The growth was exteriorized for later removal. The postoperative diagnosis was tumor of the ileum, type undetermined, and peritonitis.

The patient was returned from the operating room to the ward in good condition. He was given intravenous fluids and sulfadiazine in addition to the routine postoperative care. There was a great deal of abdominal distention which was difficult to control. At one time during dressing of the wound flatus escaped from the exteriorized tumor. There was also fecal drainage. On June 19, 1945, he began complaining of shortness of breath and his pulse was weak. The respirations gradually became labored and he expired at 6:35 P.M., June 19, 1945.

*Autopsy.*—External examination showed a well-developed and well-nourished white male. The abdomen was distended and tympanitic. In the right lower quadrant there was a recent surgical wound. In the central portion of the incision a mass attached to small intestine had been exteriorized.

Intestinal Tract: There was no peritonitis. There was a marked ileus with distention of the entire small bowel above the exteriorized mass. The appendix had recently been removed. Examination of the tumor mass itself showed that it was a diverticulum located 24 inches above the cecum. It measured two inches in length and two and one-quarter inches in diameter. Its opening was the same size as the lumen of the small intestine. Grossly, it was a purplish-red color and there was a small fistulous opening at its tip. On cut-section it was seen that most of the diverticulum was made up of a firm, grayish-white tumor. It was quite homogeneous for the most part but there were small areas of cystic change or necrosis.

Examination for metastases revealed no involvement of the lymph nodes. The liver contained a great many umbilicated tumor nodules. These were firm, white in color, and well-demarcated from the surrounding liver tissue. They measured in cross diameter about two to three centimeters each, and a good many of them showed central necrosis.

*Microscopic Study of Tumor and Metastases.* The sections showed an extensively infiltrating new growth. The cells varied in size and shape but in a good many places were definitely of cuboidal and columnar structure and were arranged in acinus formation. There were moderately hyperchromatic and an occasional mitotic figure was seen. There was a loose fibrous tissue supporting stroma. There was an occasional mitotic figure. The lining cells of the diverticulum were definitely columnar. There was some edema of the mucous covering with slight infiltration of round cells.

In the liver there were metastases which presented the same general histologic pictures as the tumor noted in the diverticulum. However, the tendency towards glandular structures was less pronounced. The tumor cells were more dense and there was more fibrous tissue.

## SUMMARY

There is presented as an addition to the literature a case of carcinoma of Meckel's diverticulum. Previously, seven cases had been reported by Albright and Sprague, and another was added by Weir. This case brings the total number of adenocarcinomas to seven, of which one originated in gastric mucosa. Two medullary carcinomas now bring the total number to nine.

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# ENTEROGENOUS CYSTS

## REPORT OF CASE INVOLVING THE RECTUM

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ENTEROGENOUS CYST is a term applied to congenital cysts arising from the gastro-intestinal tract and occurring in any part of the tract from the esophagus to the anus.[19] This definition has been broadened to include tubular duplications of the intestinal tract. Much confusion has arisen due to the use of a wide diversity of terms to describe this condition, such as enteric cyst, enterocystoma, ileum duplex, unusual Meckel's diverticulum, giant diverticulum, *etc.* In this paper, the authors will include all these terms under the single term of enterogenous cyst. An instance of this developmental anomaly involving the rectum will be presented, with a brief review of the literature and discussion of the etiology.

*Classification.*—Intra-abdominal cysts and meseinteric cysts may be classified as follows:

1. Congenital cysts:
   (a) Lymphatic or chylous cysts.
   (b) Enterogenous cysts.
   (c) Urogenital cysts.
   (d) Dermoids or teratoids.
2. Neoplastic cysts.
3. Inflammatory cysts, such as hydatid.

Discussion in this paper is limited entirely to those arising from the gastro-intestinal tract. The classification given above is a composite of those suggested by Ewing, Peterson and Parsons.[6, 16, 17]

The literature on enterogenous cysts is inseparable from that of the general class of mesenteric cysts. The confusion makes it almost impossible to determine the precise incidence of enterogenous cysts. Some idea of the rarity of the condition can be gained by a review of the incidence of mesenteric cysts. The reported cases of enterogenous cysts will be discussed more completely under the heading of treatment.

According to Roller,[18] the first cyst of the mesentery was found at autopsy in the 16th century and, since that time, the condition has come to be considered one of the rarest of abdominal tumors. It is usually stated that be-

tween 200 and 400 mesenteric cysts are reported in the literature. It is stated that no mesenteric cysts were found at the Los Angeles General Hospital from 1912 to 1929. Snyder[22] concurs in stating that mesenteric cysts are among the rarest of abdominal tumors, and quotes Judd that in 820,000 admissions to the Mayo Clinic 25 cases of mesenteric tumors were found, and only eight of these were cysts. The Massachusetts General Hospital reports only six cases from 1900 to 1926.

As far as the location of enterogenous cysts is concerned, over half the cases occurred in the small bowel and, of these, about half in the ileum.[23] Dockerty, Kennedy and Waugh[4] state that 85 per cent of enterogenous cysts involve either the cecum or ileum, and that the symptoms are usually obstructive. Ladd[12] has reported a series occurring as follows: four of the ileum, and one each of the stomach, duodenum, jejunum, mediastinum, upper lobe of the lung, and the tongue.

By personal communication, it has been found that the Army Institute of Pathology, Army Medical Museum, Washington, D. C. has three cases of enterogenous cyst on record. Two of these involved the mesentery of the ileum and were in infants less than one year old. The third case occurred in a 31-year-old white male, and involved the mesentery of the lower ileum. This institute had no enterogenous cysts involving the large bowel.

Enterogenous cysts of the rectum are extremely rare. McClanahan and Stone[15] report two cases, Hullsiek[11] reports four cases, and Ladd and Gross[11] report one case.

*Embryology.*—Enterogenous cysts present a wide variation in location, size, shape, relation to the intestinal wall and lumen, and relation to the mesentery. No single theory as to their origin can satisfactorily explain all the cases observed. There are three different theories concerning the embryogenesis of enterogenous cysts or intestinal duplications, which, between them, can adequately account for the gamut of variations noted clinically.

An often suggested mode of origin for enterogenous cysts is that they result from aberrations in the development of a Meckel's diverticulum. This fairly common diverticulum is the persistent vitelline duct, originally connecting the yolk sac and the intestinal tract. It usually arises from the antimesenteric portion of the terminal ileum, is normally obliterated before birth, but persists in about 2 per cent of people. It is conceivable that abnormalities in the development of Meckel's diverticulum may cause it to be pinched-off and, thus, give rise to enterogenous cysts or intestinal duplications, which may or may not communicate with the intestinal lumen. A considerable proportion of enterogenous cysts arise in the ileocecal region, and this mode of origin is a plausible explanation for their development. However, it does not explain those cases located along the tongue, esophagus, duodenum, colon or rectosigmoid, nor does it explain those cases which have separate mesenteries.

A second mode of origin, that has been stressed by Ladd and Gross,[11]

and others, is based on an observation by Lewis and Thyng, in 1907, who reported frequent diverticula at various levels of the fetal intestinal tract in the pig, rabbit, and man. These diverticula are found in 20-to-30-mm. embryo (eight–nine weeks), usually on the antimesenteric border, and normally disappear completely. It is not difficult to visualize how such a residual outpouching can become pinched-off and give rise to cystic structures with the histologic components of the intestinal wall. They may be located anywhere from the mouth to the anus; they may be in a submucous, intramural, subserous or intramesenteric position; and they may communicate with the bowel or be completely separated from it. However, this mode of origin will not explain the long tubular intestinal duplications that have been observed by Ladd and Chisholm, and Feingold and Shulman,[13, 7] nor those that have a separate mesentery or more than one communication with the bowel lumen.

A third mode of origin has recently been described by Bremer.[2] In the 10 mm. embryo (about six weeks) just prior to the rapid lengthening of the intestinal tract there is an hyperplasia of the epithelial cells producing a marked reduction in the size of the lumen, or even occluding it. This solid stage may occur at any point along the intestinal tract. These epithelial cells secrete a fluid which forms small vacuoles. These vacuoles gradually coalesce and reform the lumen of the tube. In rare cases a chain of vacuoles may coalesce but not reunite with the main lumen, producing two separate lumens. As growth progresses the two lumens become more separated and each comes to be surrounded by a submucosa and muscular layer. Thus, there is produced a double-barrelled tube or duplication of the intestinal tract. The duplicated portion may be a long tubular structure or it may be short and rounded; it may be within the wall of the intestine or completely separated from it even to the point of having a separate mesentery; it may communicate with the intestinal lumen at both ends, at one end, or be completely sealed off.

It is very likely that any of the above-mentioned anomalies of development may give rise to enterogenous cysts. The structure ultimately found clinically is the result of superimposed factors such as hemorrhage, infection, intracystic pressure, blood supply, and relation to surrounding viscera.

*Diagnosis.*—As far as symptomatology and diagnosis of enterogenous cysts are concerned, no pattern of symptoms is presented with sufficient regularity to make preoperative diagnosis possible in a very high percentage of cases. Many reported cases have been operated upon because of acute intestinal obstruction of undiagnosed etiology and, at the time of celiotomy, enterogenous cysts have been found. This is particularly true of that series of cases occurring either in infants or very young children. Another group of cases does not present obstructive signs and symptoms but presents an undiagnosed abdominal tumor mass of a cystic nature which ultimately proves to be an enterogenous cyst. These cases are often adults in whom the condition remained asymptomatic for a long period of time and became

mildly symptomatic with increase in size and pressure of the cyst upon other organs.

*Treatment.*—Treatment of enterogenous cysts is obviously surgical; and one of the following procedures is recommended: (1) Resection. (2) Enucleation. (3) Marsupialization. Any plan of treatment must, of course, be governed by the condition of the patient at the time of operation and, if surgical conditions are not ideal for carrying out a complete eradication of the cyst, some form of palliative and temporizing procedure must be selected. This is particularly true of those patients who have developed acute intestinal obstruction as a result of a cyst, and in whom some form of decompressive measure as an initial operation may be the primary treatment of choice, followed at a later date by a more definitive surgical procedure. If the case is an elective one and surgical conditions are ideal, either resection or enucleation should be chosen, depending upon the location of the cyst and its attachment to the gastro-intestinal tract. If the attachment is such that the cyst cannot be completely eradicated and recurrence avoided, then resection of the cyst and the attached bowel, with some type of anastamosis to restore continuity, is preferable. In some cases enucleation is not only feasible but can be performed successfully with a high percentage of cure. Marsupialization is condemned by most authors and should be used only if no other form of surgical treatment can be followed. When used, it results in a greatly prolonged period of drainage and, very often, in recurrence.

Aschner[1] collected, and briefly reviewed, 27 patients from the literature, the majority of whom were children, mainly infants, and all involving the cecum or ileum. Seven were successfully operated upon. Drennen[5] reports three cases occurring in the ileocecal region. One was in a child, age nine months, suffering from acute intestinal obstruction; the cyst was located within the wall of the cecum and resection was performed with recovery. The second was a child, age two, with symptoms and signs of obstruction and bloody stools, who, upon operation, had an intussusception which was impossible to reduce. An ileosigmoidostomy was performed, with a fatal outcome, and the specimen showed a cyst of the cecum. The third was a woman, age 21, with a diagnosis of acute appendicitis, who had a cyst in the lower cecum which was removed without resection and with recovery. Gardner and Hart[8] report an enterogenous cyst of the duodenum in a girl, age 15, which was removed, and the patient recovered. Green[9] reports a boy, age six, operated upon for obstruction, who presented a cyst located in the mesentery of the transverse colon, which, histologically, showed the structure of the small intestine. This was treated by marsupialization, with recovery. Green[9] also reports a man, age 56, with a long history of right lower quadrant pain who, at operation, had a large enterogenous cyst attached to the terminal ileum. The cyst was removed, with recovery. Shallow[20] reports a male infant, age five months, who was admitted with enormous abdominal distention and obstruction. At operation, a very large cyst, containing

1,500 cc. of fluid, was found attached to the small intestine, and 10 cm. from the ileocecal junction. This was an enterogenous cyst, which was treated by a primary resection, with a fatal result. Carlson[3] reports an enterogenous cyst occurring in a male, age 22, with obstructive symptoms. The cyst was not removed, but two enterostomies were performed within 12 hours above the point of obstruction. The patient died and, at autopsy, was found to have an enterogenous cyst of the mesentery. Grove and Porch[10] state that resection is usually safer than attempting to remove the cyst from the bowel, and report a 22-year-old male who was operated upon with a preoperative diagnosis of acute appendicitis, but was found to have an enterogenous cyst located 40 cm. from the cecum and closely adherent to the terminal ileum. Resection and end-to-end anastamosis were performed, with recovery. Ladd[12] reports the following cases with their management: (1) A 35-day-old baby, with a cyst of the upper duodenum, which was resected and a posterior gastro-enterostomy performed; this case recovered. (2) A six-months-old infant, with a perforated duplication of the jejunum and peritonitis. Enterostomy was performed; the patient died. (3) A two-months-old female, with a duplication of the terminal ileum upon whom resection and end-to-end anastamosis was performed; with recovery. (4) A 19-months-old child, with a cystic duplication of the bowel and hemorrhage. The cyst was removed; the result is not stated. In these cases, reported by Ladd, vomiting was a prominent symptom in all, and a tumor mass was presented in six of seven abdominal cases. Ladd[12] states that the treatment is surgical, with no undue delay, and that seven of ten patients thus treated were relieved and three died. Sherwin[21] reports a female, age four years, with obstructive symptoms, who presented a tumor of the ileocecal junction; found to be an enterogenous cyst. This was treated by resection and anastomosis, with recovery. Sherwin[21] states that the first choice of treatment is enucleation, with resection as second choice and, lastly, marsupialization should be used if all other procedures are impossible.

Many writers state that the rectum is the rarest site for occurrence of enterogenous cysts. McClanahan and Stone[15] reported two cases originating from the rectum. The first case was a woman, age 48, with a cystic mass about the size of a walnut, located between the posterior wall of the rectum and the coccyx, about 5 cm. within the anal orifice. This was removed extraperitoneally by an incision posterior to the anus, with removal of the coccyx and dissection of the cyst from the posterior wall of the rectum. Pathologically, this was found to contain all layers of the intestine, with tall columnar epithelium of the mucus-secreting type. The second case was a male baby, age one month, who presented signs and symptoms of incomplete intestinal obstruction, with a mass covered with rectal mucous membrane projecting through the anus. This was treated first by aspiration, and later removed through an incision to the right of the rectum, enabling separation of the cyst from the rectal wall. This, too, revealed all layers of the intestine with a well-defined mucosa of columnar epithelium. Both cases

recovered. Hullsiek[11] reported four cases of enterogenous cysts of the rectum palpable as extrarectal masses and varying in size from a hazelnut to a walnut. All four of these were removed surgically from within the rectum. Of 18 cases reported by Ladd and Gross,[14] one was of the rectum, in a six-months-old infant, and measured 5 x 2.5 x 2.5 cms. This case was treated by excision of the cyst.

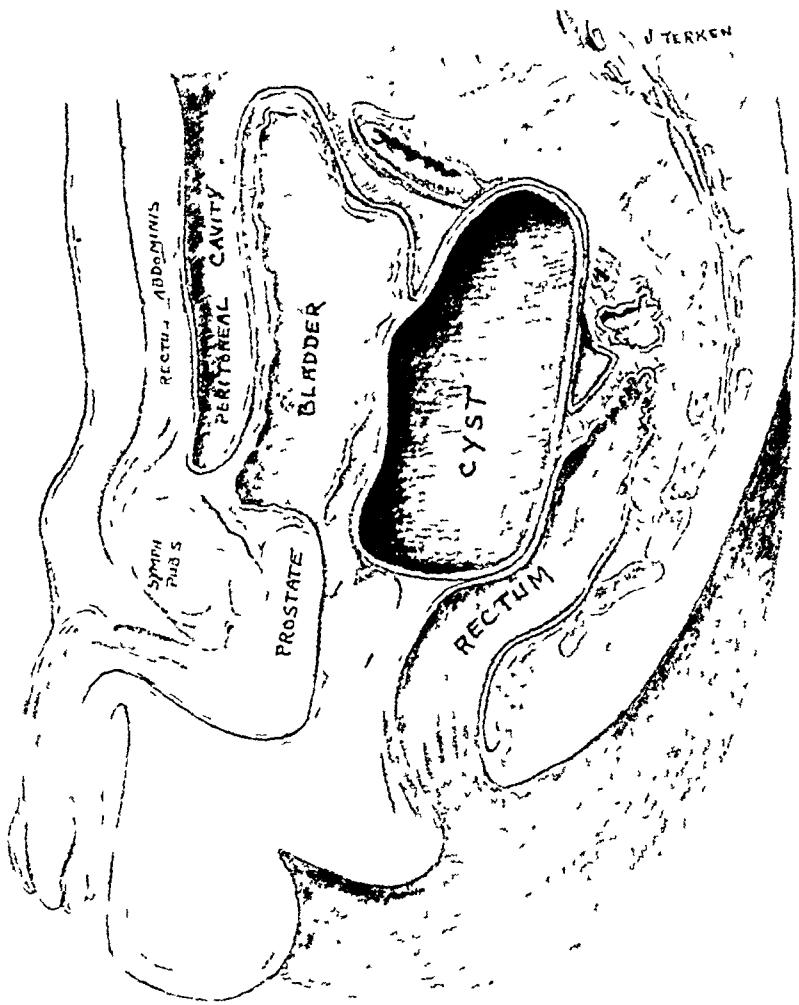



FIG. 1.—Lateral drawing showing cyst between bladder and rectum.

**Case Report.**—E. P. G., a 29-year-old, white male, complained of intermittent epigastric pain for 2.5 months prior to admission. His present illness began on March 4, 1945, about two hours after eating the evening meal, when he first noted severe epigastric pain, nausea and vomiting. The attack lasted about one and one-half hours, but epigastric soreness remained throughout the night. The following day he experienced a similar attack of epigastric pain which, he states, was relieved by an alkaline drink. On the third day, he developed an attack which was much more severe than the previous ones, and he was hospitalized at an Army General Hospital, where expectant treatment was given. Gallbladder roentgenologic study was reported to be

normal. Right subcostal soreness persisted. An interim of three weeks elapsed before another attack of pain. At this time, he was again hospitalized at an Air Force Station Hospital, and a second gallbladder roentgenologic study was done, as well as a gastro-intestinal series; both of which were reported normal. Following each attack, the patient was discharged from the hospital, with a diagnosis of epigastric pain simulating cholecystitis, cause undetermined. On April 24, 1945, about six weeks following onset of his illness, a third hospitalization was necessary because of an attack of upper abdominal pain similar to previous episodes described At this time a rectal examination disclosed a cystic mass which filled almost the entire pelvis. On May 14, 1945, he was transferred to the AAF Regional Station Hospital, Westover Field, Mass. for definitive treatment. A history of urinary complaints disclosed that for the past two years the patient had noticed a decrease of his bladder capacity, with a slight frequency of urination and occasional nocturia. On a few occasions at night he had experienced suprapubic pain, with moderate difficulty in starting the urinary stream. At no time had he noticed gross blood in his urine.

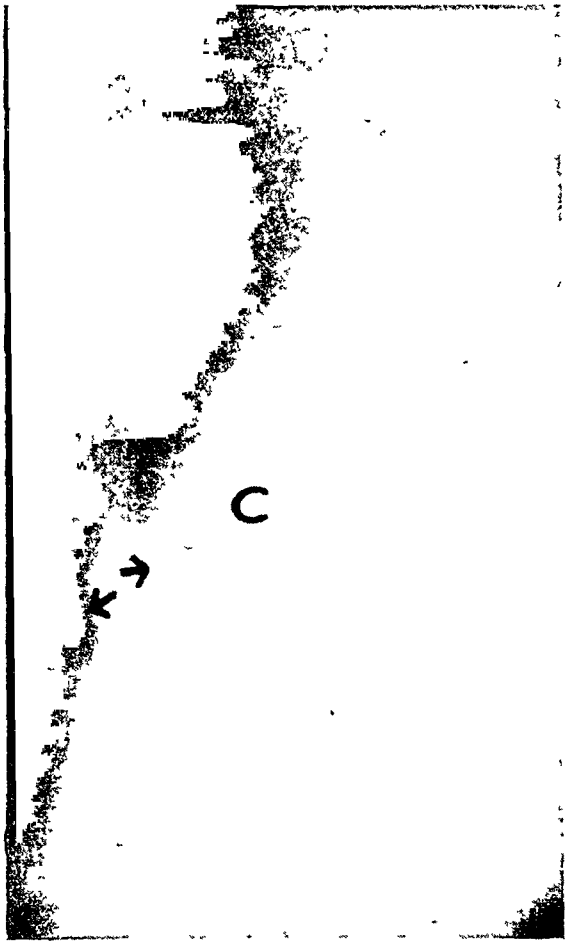



FIG. 2—Lateral view of cystogram. (B) Tubular compression and elevation of bladder by the cyst (C).

*Past History:* He denied weight loss. He described a backache of ten years' duration which was not incapacitating nor did it disturb his sleep. There was no history of major illness or operation. The family history was noncontributory. In civilian life this patient was an assistant production manager in a manufacturing concern His Army occupation was that of a chauffeur.

*Physical Examination:* The patient was well-developed and well-nourished. Weight about 180 pounds. There was a rather pronounced tenderness in the right subcostal margin extending down to the iliac crest. No masses were palpable. Rectal examination disclosed a nontender mass, which was estimated to be about the size of a large grapefruit. This was moderately cystic and apparently attached to the floor of the bladder, but definitely extrarectal (Fig. 1). It was ballotable to pressure in the suprapubic region. Sigmoidoscopic examination was not remarkable except for a bulging mass visualized on the anterior surface of the rectum.

*Laboratory Studies:* Repeated blood counts and urinalyses were normal. Blood serology was negative. Blood N.P.N., sugar, icteric index, bilirubin, total protein, cephalin flocculation, chlorides, cholestrol, calcium and phosphorus were all within normal range.

On cystoscopic examination, the bladder walls were smooth and not injected. Bladder capacity was diminished to four ounces. The trigone was markedly elevated. No diverticula or tumor masses were visualized. Both ureters were catheterized and retrograde pyelograms made. The kidneys and ureters were normal. A cystogram was

done after the cystoscope was removed and revealed the bladder to be displaced anteriorly so markedly that the cystogram had a tube-like appearance (Fig. 2).

A plain film of the abdomen, anteroposterior view, revealed a rounded elliptical mass, 10 x 11 cm., located between the lower two-thirds of the bladder and the rectal ampulla. This mass projected into the hollow of the sacrum overlying S1 and S2 and extended down to the level of the symphysis. Two linear calcific plaques, 3 cm. long, were visualized along the left border (Figs. 1 and 3).

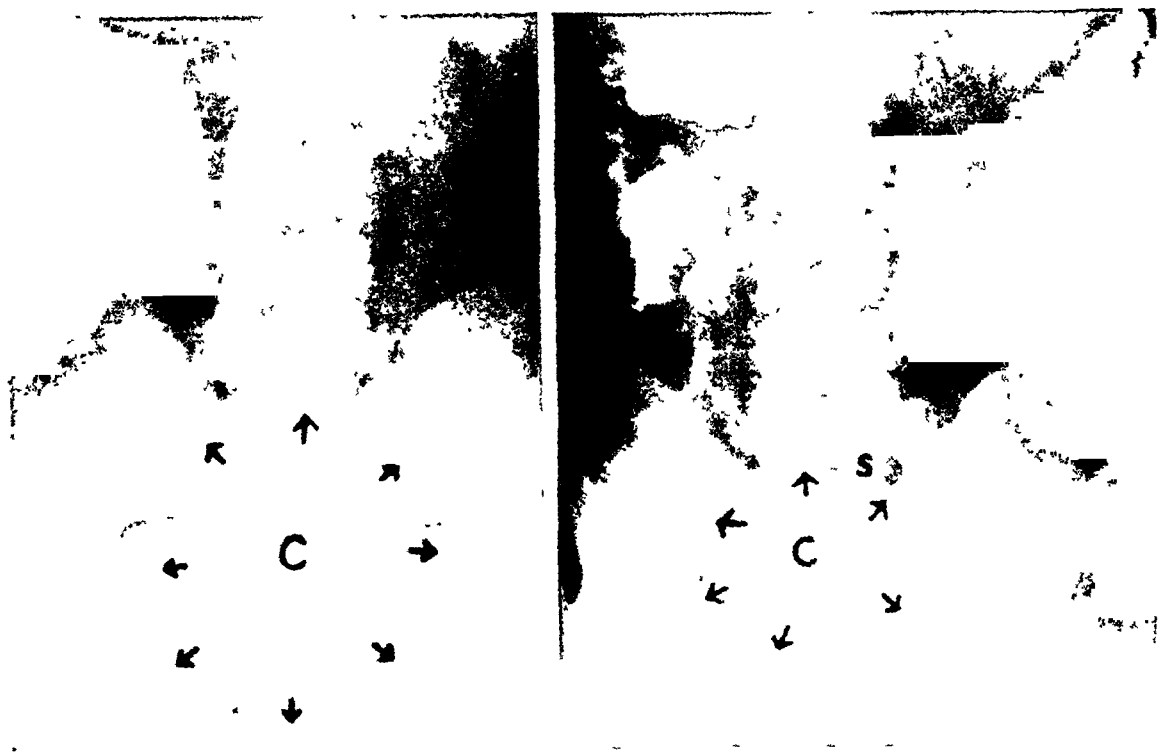



FIG. 3 FIG 4

FIG. 3.—Plain film of abdomen showing cyst (C) outlined by arrows.
FIG. 4.—Barium enema showing displacement and compression of sigmoid colon (S) by the cyst (C).

Barium enema revealed marked compression of the rectal ampulla by the mass described above (Fig. 4).

*Preoperative Diagnosis:* This patient presented a large cystic pelvic mass displacing both the bladder and the sigmoid colon. Diagnoses considered preoperatively were: (1) diverticulum of the bladder; (2) enterogenous cyst; (3) dermoid cyst; and (4), remotely, an aneurysm. Diverticulum of the bladder was excluded by cystoscopic examination. Aneurysm was excluded by the physical characteristics of the mass and normal oscillometric tests of the lower extremities.

*Operation:* In order to facilitate anatomic orientation, ureteral catheters were introduced just prior to operation. Under continuous spinal anesthesia, a transperitoneal approach was made through a midline suprapubic incision, and an extraperitoneal mass, about the size of a large grapefruit, was exposed. The entire mass was separated down to its attachment to the anterior wall of the rectum. At this point it contained a calcific plaque. The caudal end of the cyst extended to the prostate. The left seminal vesicle was exposed but not disturbed. During the operative procedure the cyst wall ruptured and a large amount of thick mucoid material escaped. This showed no gross evidence of pyogenic infection Frozen sections, at the time, revealed no evidence of malignancy. The entire cyst was removed except that small portion of the wall densely adherent to the anterior wall of the rectum.

FIG. 5

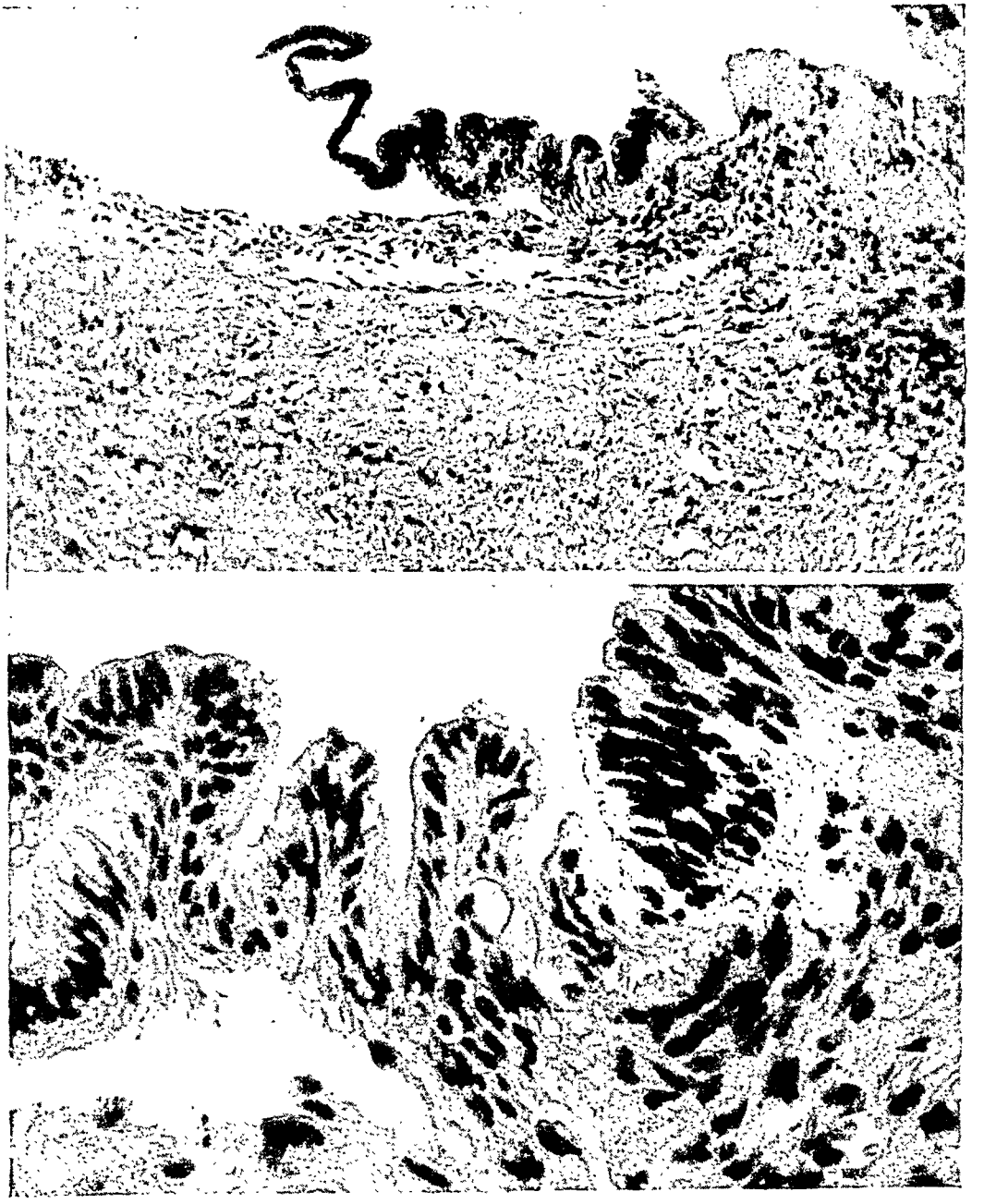


FIG. 6

FIG. 5.—Low power view of cyst wall showing remnant of epithelial lining.
FIG. 6.—High power view of tall columnar mucus-secreting epithelium.

*Pathologic Report.—Gross:* Specimen consists of five pieces of tissue forming the wall of a cyst, and measuring in aggregate 12 x 11 cm. The outer surface has an irregular roughened yellow-gray appearance and is covered by many thin plaques of calcium. The inner surface of the cyst is quite smooth and varies in color from grayish-white to red. No definite mucosal lining is discernible. The cyst contents consist of about 600 cc. of thick, tenacious mucoid material having the general appearance and consistency of partially coagulated egg white. The wall ranges from 1 to 8 mm. in thickness. The thicker portions of the wall on cross-section bear a striking resemblance to the wall of the intestinal tract. There are scattered areas of calcification within the cyst wall.

*Miscroscopic.*—Eight sections H and E. The sections show a cyst wall with considerable variation in thickness. The thinner portions of the wall are composed, for the most part, of dense collagenous and hyalinized connective tissue with scattered small foci of hemorrhage, round cell infiltration, plaques and deposits of calcium. The thicker portions of the wall show very clearly the four coats of the intestine. A few tiny shreds of epithelium are present. This is of the tall columnar, mucus-secreting type (Figs. 5 and 6). The remainder of the mucosa is quite thickened and hyalinized. The submucosa contains many fairly large collections of small lymphocytes suggestive of lymphoid follicles. There is a thick well-defined layer of smooth muscle with muscle bands running in several planes. The usual clear demarcation between the circular and longitudinal muscle bundles is not evident. The serosal coat is thickened and edematous, with many small and a few fairly large areas of hemorrhage. There are many calcific plaques and small deposits of calcium in all portions of the wall, most prominent in the submucosa and serosa. There are many small scattered collections of lymphocytes with an occasional polymorphonuclear neutrophil and eosinophil.

The histologic picture is that of intestinal wall which had undergone fibrosis, hyalinization, deposition of calcium and pressure atrophy of the epithelial lining. The cyst undoubtedly represents a developmental anomaly of the lower portion of the intestinal tract. *Pathologic Diagnosis:* Enterogenous cyst.

*Postoperative Course:* Convalescence was not remarkable until the 12th postoperative day. The wound had healed *per primam.* At this time, the patient had an attack of epigastric pain, nausea and vomiting with a moderate febrile reaction, similar to that experienced preoperatively. Five days following the onset of this attack, temperature rose to 103°F., and he continued with an intermittent fever for a period of eight days, at which time, the epigastric discomfort subsided and temperature returned to normal limits. The convalescence was subsequently uneventful. Four weeks following the enterogenous cystectomy a repeat gallbladder roentgenologic study was done and, at this examination, there were multiple calculi visualized within the gallbladder. It is interesting to note, at this point, that the symptoms of epigastric pain, nausea and vomiting were due unquestionably to the cholelithiasis and that the enterogenous cyst was an incidental finding and produced symptoms referable only to the urinary bladder and the low backache of which he had complained for a number of years.

A cholecystectomy was performed approximately five weeks following the initial surgery and the diagnosis of cholelithiasis confirmed.

Rectal palpation at the end of ten weeks disclosed only slight residual induration at the site of attachment of the enterogenous cyst to the anterior rectal wall. The urinary bladder symptoms had subsided and the patient returned to duty symptom free.

SUMMARY

A case of an unusually large enterogenous cyst arising from the rectum, with successful removal, is reported. The literature pertaining to enterogenous cysts, their origin, incidence and treatment, is reviewed.

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# LIPOSARCOMA OF THE MESENTERY

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TUMORS OF THE MESENTERY are comparatively rare. The following case of liposarcoma is presented because it illustrates the unusually benign course which such a lesion may take. Our patient has been observed over a period of more than six years. Despite two operations, the second one for a recurrence of the original tumor, she is at present in excellent condition.

CASE REPORT.—The patient, a 56-year-old, white, unmarried, professional woman, was seen at our clinic, on June 15, 1939, at which time she complained of mild and long-standing constipation associated with belching and bloating after meals. There was no abdominal pain, and other gastro-intestinal symptoms were absent. She had noted some slight increase in the size of the abdomen despite the fact that she had been on a reducing diet and had lost twenty pounds during the past year. She had had an uneventful menopause ten years previously, and there had been no vaginal bleeding or discharge since then. The rest of the history was non-contributory.

*Physical Examination.*—The patient was well-developed, plump, and appeared to be in good health. The blood pressure was 136/80, the pulse 84. The head, neck, and chest were normal. The abdomen was obese and appeared distended and somewhat asymmetrical. A large, firm, somewhat nodular tumor was palpable in the abdomen. It extended upwards to half way between the umbilicus and xiphoid. This mass was freely movable and not tender. On pelvic examination, it could not be determined if the tumor was attached to the uterus. Laboratory examinations were negative. A diagnosis of fibromyoma uteri or ovarian tumor was made.

The patient entered the Johns Hopkins Hospital, under the care of Dr. Richard TeLinde. On examination there, it was believed that ascites was present and that the tumor was floating in free fluid. Pelvic examination revealed a one-finger introitus, a small conical cervix reaching high in the vagina, and a mass about three times the size of the normal uterus present anteriorly in the usual position of the uterus. A fixed tumor mass was thought to be present posteriorly on the left. Neither ovary could be palpated. It was believed that while a fibroma of the ovary might account for the picture, an ovarian carcinoma with ascites was the most likely diagnosis.

*Operation.*—June 30, 1939. A pelvic examination, under ether, was made preoperatively. At this time, a very small, freely movable uterus could be felt anteriorly, and no masses were present in the fornices. On palpation, a large cystic mass seemed to occupy the whole abdominal cavity. The diagnosis was consequently changed to intra-abdominal, nonpelvic tumor.

On exploration, a large cystic tumor, encapsulated in a glistening white covering, was found. This mass contained solid areas in it. It rose high in the abdomen from the gastrocolic ligament, and was closely adherent to the large and small bowel and to the greater curvature of the stomach. There was no attachment to the pelvic organs. The tumor was freed from its attachments without injury to stomach or intestines and delivered *en masse*, after which the abdomen was closed. The patient made an entirely uneventful recovery and was discharged in good condition. Histologically, the tumor was felt to be a benign fibrolipoma containing "peculiar looking giant cells" (Fig. 1).

Following her recovery the patient returned to a strenuous and responsible government position and found that she could carry her work as well as ever. She was entirely asymptomatic until the end of 1944, when she again noted some enlargement of the abdomen and slight indigestion, consisting of belching, flatus, and fulness after meals. Moderate constipation was still present but was no worse than it had been for many years. She had lost a little weight.

*Physical Examination.*—December 14, 1944. The patient was an obese, healthy appearing, 61-year-old, white female. Findings were negative except for the abdomen. The abdominal wall was seen to be slightly elevated in the left para-umbilical region. In this area a mass about four inches in diameter could be felt. This was smooth, nonpulsating, nonfluctuant, and slightly movable from side to side only. It was dull to percussion. The liver edge could be felt on deep inspiration. Rectal examination re-

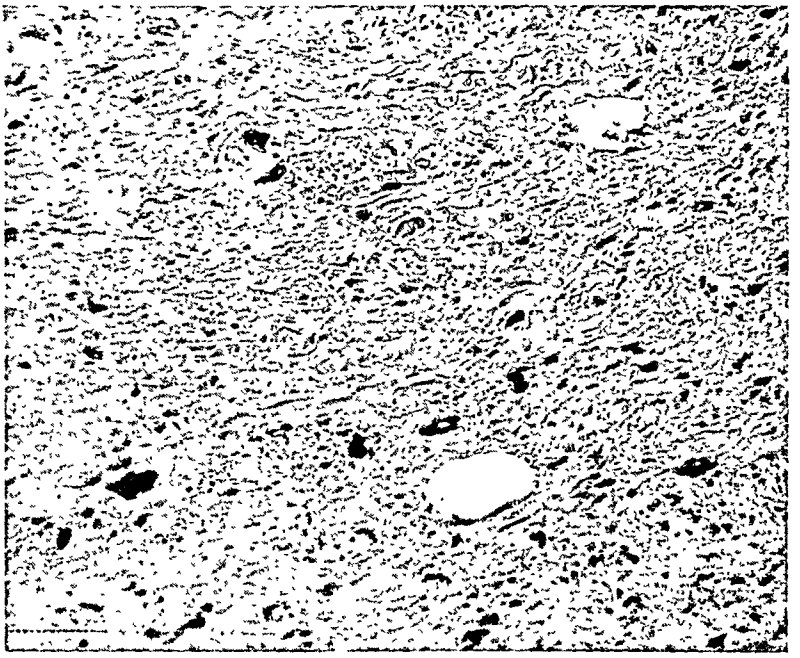


FIG. 1.—Photomicrograph of first tumor, removed June 30, 1939. Note presence of large giant cells. (x 150)

vealed a small, anterior, freely movable uterus. Laboratory studies were negative. A gastro-intestinal series showed that the tumor was outside the intestine and was pushing the stomach upwards and the transverse colon downwards. The diagnosis of a recurrent fibrolipoma was made.

*Second Operation.*—January 17, 1945. A celiotomy was performed at the Garfield Memorial Hospital, Washington, D. C. by Dr. Herbert Schoenfeld. On opening the abdomen, it was found that the gastrocolic omentum contained numerous discrete tumor masses, varying from the size of a marble to that of a walnut. An encapsulated tumor, about five inches in diameter, was present in the inferior leaf of the transverse mesocolon. This was easily shelled out. Several of the small masses were released from the gastrocolic omentum and numerous thickened areas of fat were palpable throughout this omentum. Because all the tumor-bearing tissue could not be mobilized and because of local damage, the transverse colon was resected. Following this, a daughter tumor, the size of a walnut, was found under the splenic flexure of the colon and was shelled out. The abdomen was then closed. The patient had a somewhat stormy postoperative course,

became considerably distended, and did not respond well to supportive measures. A blow-out at the suture site was feared. Decompression was, therefore, performed, January 20, 1945, by means of an appendicostomy. She made an excellent response to this procedure and, February 6, 1945, 20 days postoperatively, she was discharged from the hospital in good condition except for some infection and drainage at the site of the cecostomy incision. A local sinus of the abdominal wall which formed in this area was excised in May, 1945, and following this the wound healed completely.

The patient has returned for follow-up visits, and when last seen, in November, 1945, she was back at her job and in excellent condition. She stated that her bowels "had never been so good."

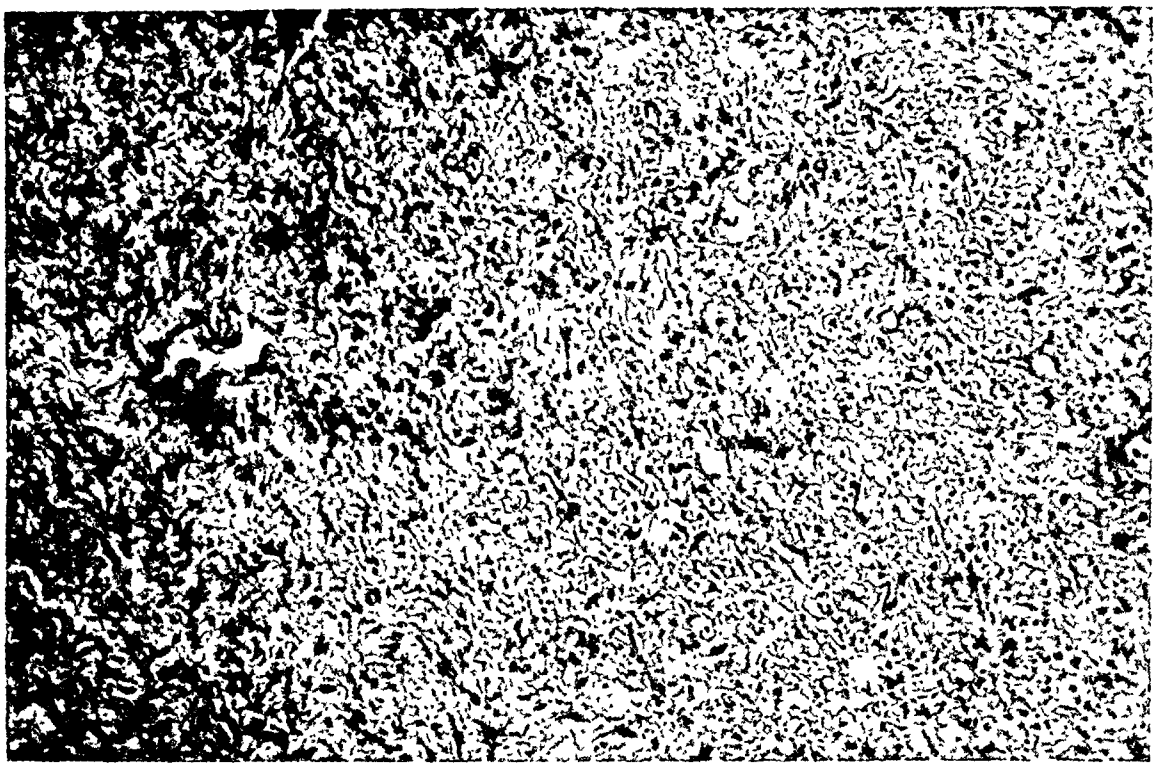


FIG. 2.—Photomicrograph of second tumor, removed January 17, 1945. A few small giant cells are present. The stroma is much more cellular but the majority of cells are well differentiated and benign in appearance. (x 150)

The second tumor (Fig. 2) and sections of the first growth were studied by Dr. Janvier W. Lindsay, pathologist of the Garfield Memorial Hospital, and by Col. J. E. Ash, and his associates, of the Army Institute of Pathology. It was their opinion that all slides, including those of the first operation, were consistent with a diagnosis of low grade liposarcoma.

DISCUSSION.—The above case presents a number of interesting aspects. Symptomatically, these tumors have been divided into two groups by Hart.[1] In the first group are the "silent" growths which are discovered accidentally on physical examination. In the second, are those tumors giving abdominal symptoms which vary from those of mild indigestion, distention, constipation, *etc.*, to those of the "acute surgical abdomen." The more dramatic latter picture may be the consequence of intestinal obstruction resulting from volvulus or intussusception, or from accidents, such as hemorrhage into the tumor or peritoneal cavity, rupture of a cyst, with or without peritonitis, or

infection within a cystic tumor itself. Obviously, tumors in Group I may progress to Group II. Our patient would fall into the second group, but the symptoms were indeed so minimal that the physician who first saw her expected to find a negative abdomen until he proceeded to the physical examination.

Diagnostically, these tumors present a considerable problem. Their true nature is seldom recognized before operation.[7, 8] In women, they are often mistaken for ovarian or uterine growths, as was the case with our patient. In cases where the tumor has been recognized to be nonpelvic in origin the diagnosis of retroperitoneal sarcoma, tumor of the kidney, hydatid cyst, tuberculoma, *etc.*, has been made. When the picture is complicated by an acute abdominal crisis recognition is much more difficult, and patients have gone to surgery with the preoperative diagnosis of intestinal obstruction, acute appendicitis, appendiceal abscess, acute cholecystitis, ruptured ulcer, *etc.* One of the chief stumbling blocks to preoperative diagnosis lies in the fact that the condition is sufficiently rare so that it is not likely to be considered. However, an intra-abdominal tumor lying outside the pelvis, solid or cystic, movable from side to side, and shown roentgenographically to be outside the G. I. and G. U. tracts should make one suspect this diagnosis.[2]

Surgical technics in the management of solid mesenteric tumors divide themselves into two types. Local removal may be feasible, as was the case at our patient's first operation, or a partial resection of the intestine may have to be performed for various technical reasons, such as existed at her second operation. The operative mortality is variable. Mills[4] states that it is in the neighborhood of 20 per cent, without giving the source of this estimate. In Hart's[1] collected series of explored patients, which was 66 in number, 7 patients, or 10 per cent, died after simple celiotomy, with biopsy, 12 patients, or 18 per cent, died after enucleation, with or without resection, and 47 patients, or 72 per cent, recovered after a major surgical procedure. The mortality rate is unfavorably influenced by the presence of an acute surgical emergency; by the necessity for extensive resection; and by the presence of a far-advanced inoperable condition.

Pathologically, mesenteric tumors have been classified into the solid and the cystic. Histologically, they are primarily divided into the benign and the malignant, and may then be subdivided into many more precise categories. Sarcomata are the most frequent among the malignant tumors. It is not uncommon to have a variation of opinion among pathologists as to the nature of the tumor, and disagreement may exist on the presence or absence of malignancy.[1] Time may help to make the differential point, as it did for us. The prognosis, discounting operative mortality, depends, of course, on the histopathology found. Rankin and Major,[6] and Judd and Crisp,[3] all of the Mayo Clinic, feel that the outlook in malignant tumors is unfavorable. However, review of the literature does not bear out such a general conclusion, and other authors do not agree with it.[1, 4, 5] The degree of malignancy of mesenteric tumors appears to be very wide. While there are reports of

certain cases in which such far-advanced metastases were found that removal was out of the question, there is a considerable number of cases in which the malignancy was of a low grade and the outlook for prolonged survival appeared to be excellent. That a sarcoma may be consistent with a long, productive survival is well illustrated by this case. We were fortunate enough to observe our patient over an unusually long period of time. Were a similar opportunity given to others, they might report the same tale.

SUMMARY

A case of low grade liposarcoma of the mesentery is presented. The patient, now a 61-year-old, white female, has undergone two major surgical procedures for this condition, and is at present in excellent health. Some of the interesting features of this case and of these tumors in general are discussed.

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# SPLENECTOMY

## REMOVAL OF A SPLEEN WEIGHING 5,450 GRAMS

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SPLENECTOMY is a well-standardized operative procedure, and the results have been very satisfactory if done when the proper indications exist.

The generally recognized indications for removal of the spleen are: 1. Rupture of the spleen. 2. Early congestive splenomegaly (Banti's syndrome). 3. Idiopathic thrombocytopenic purpura. 4. Familial hemolytic icterus. 5. In some cases of known (*e.g.*, chronic malaria, Gaucher's disease) or idiopathic splenomegaly, which, because of the size of the spleen, produces mechanical pressure effects upon neighboring structures (*e.g.*, stomach; diaphragm). The case herein reported belongs in the last group of cases. The enlarged spleen was believed to be the result of a chronic malarial infection.

Cirrhosis of the liver with or without an associated ascites is considered to be a contraindication for splenectomy. Because of the compromise of hepatic function the prognosis under conservative therapy is equal to that following operation, without the added risks of the latter. Other contraindications for surgery are advanced chronic debilitating diseases involving the pulmonary, cardiovascular and renal systems.

In the determination of operability, the size of the spleen *per se* is not a contraindication. The same applies to the associated anemia when present. This will be commented upon later. Each case presents its own individual problems.

In the present case, the spleen upon removal weighed 5,450 Gm.† (12 pounds), and measured 32 cm. x 25 cm. x 10.6 cm.‡ in size. To visualize more clearly the huge size of the spleen, its weight was compared to that of the body weight of the patient and found to be the equivalent of one-eighth of the latter. Following the removal of such a large space-occupying viscus, signs and symptoms referable to a sudden change in intra-abdominal pressure relations might have been expected to occur. None were observed.

In the removal of a spleen of this proportion there are certain technical points which may be considered. A longitudinal left paramedian incision is preferred with the operator standing to the left of the patient. The larger the spleen and the lower it extends towards the pelvis, the less suitable is

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† Normal: 100–250 Gm. (Gray's Anatomy).

‡ Normal: 12 cm. x 7 cm. x 3.4 cm. (Gray's Anatomy).

any other type of incision. A transverse-T extension of the incision is not considered necessary. In the mobilization of the spleen, care must be exercised to prevent tears in the parenchyma. These tears are easily produced and may result in troublesome hemorrhage. It has been the experience of one of the authors (J.L.M.) that the ease with which mobilization and deliverance of the spleen is accomplished varies in a direct ratio to its size.

A consideration of prime technical importance is the anatomic relationship between the tail of the pancreas, the greater curvature of the stomach, and the pedicle of the spleen. This relationship is constant, and its surgical importance cannot be overemphasized. A lack of knowledge pertaining to it may result in unrecognized damage to the pancreas and/or the stomach during the application of clamps to the pedicle of the spleen.

In the large spleen the exposure of the pedicle does not present the technical difficulties inherent in the small one. In the former, division of the posterior layer of the lienorenal ligament is more easily accomplished, permitting a further mobilization of the spleen. Following the division of this ligament the recognition of the anatomic relation between the pancreas and the splenic pedicle is mandatory. These structures may be separated without difficulty by blunt tissue dissection, isolating the lienal vessels posteriorly. The isolation of the spleen and its pedicle anteriorly is completed by dividing the anterior layer of the gastrolienal ligament, and clamping and ligating the contained vasa brevia. This permits retraction of the greater curvature of the stomach and completes the exposure of the splenic pedicle.

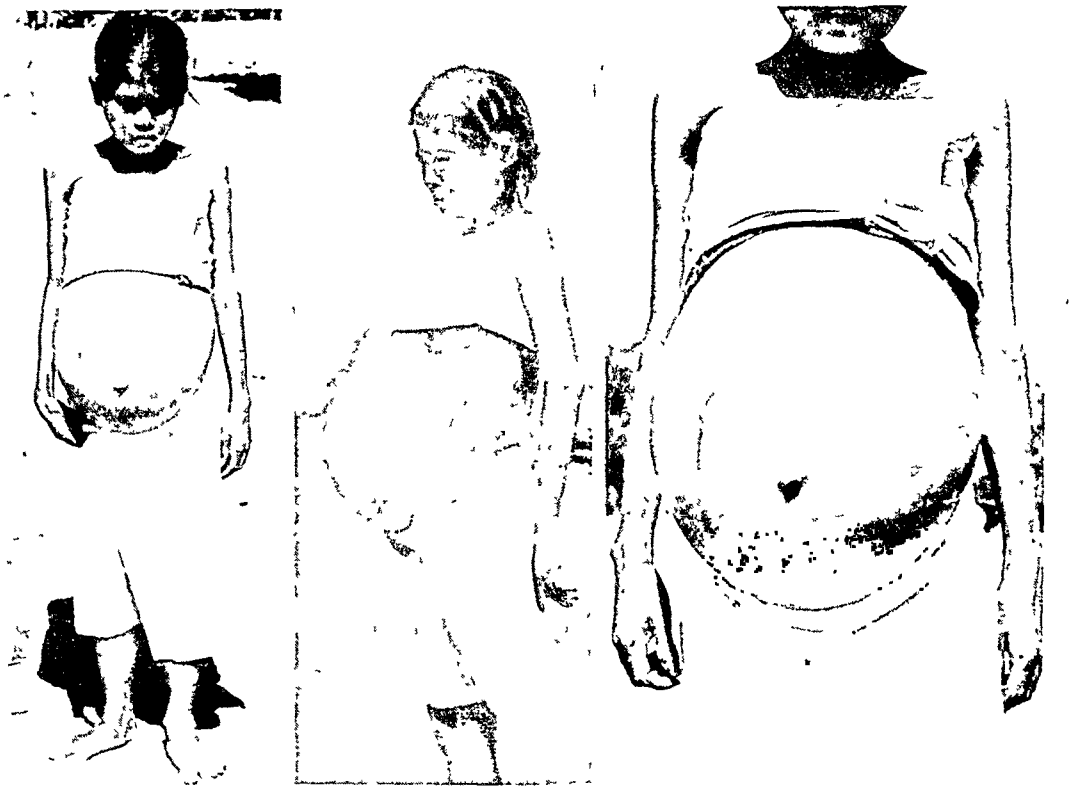
In the surgical management of the pedicle we prefer the clamp method because of the technical difficulties pursuant to the isolation and individual ligation of the huge, dilated, thin-walled vessels. The pedicle is serially clamped (triple clamp method) and divided between the two distal clamps. Double ligation (silk) of the proximal stump is performed. A reperitonization of the pedicle bed is not necessary. The wound closure is in layers without drainage.

In the case presented, a selective ligation and division of the lienal artery, followed by the intravenous administration of epinephrine had been contemplated for the purpose of contracting the spleen and autotransfusing the patient. This was not done because of the potential danger of transferring an excess of hemolyzed red blood cells into the systemic circulation. The use of fresh whole blood during and immediately following the operation was considered preferable.

In the case herein reported the spleen is one of the largest to have been successfully removed, with the recovery of the patient. In the case reported by Pick[1] the spleen weighed 8,100 Gm. Mandelbaum,[2] and his associates, reported the removal of a spleen which measured 38 cm. x 24 cm. x 13 cm. and weighed 6,822 Gm. The spleen recorded by Horsley weighed 5,890 Gm. In each of the reference cases the causative factor for the enlargement of the spleen was Gaucher's disease.

**Case Report.**—The patient, a 27-year-old Filipino female, was admitted to the hospital, January 15, 1945, with the history of a progressive enlargement of the abdomen during the past seven years. In the last year, a more rapid increase in the size of the abdomen had occurred, with an increasing dyspnea, weakness, anorexia and loss of weight. Due to the multiplicity of the symptoms produced she entered the hospital for treatment.

A review of her past history showed that she had not menstruated for two years. However, a vicarious menstruation (epistaxis) of one day's duration had occurred at regular intervals each month, the time corresponding to the expected date of her normal menstruation. She had had repeated attacks of malaria, "too many times to count."



A B C

FIG. 1.—(A) and (B). Distant photographs to demonstrate the size of the abdomen to relation to the body-size of the patient.

(C). Close-up view showing the outline of the spleen in relation to the anterior abdominal wall.

There was a progressive weight loss, the amount unknown. She weighed 96 pounds on admission.

*Physical Examination.*—The patient was a fairly well-developed but poorly nourished female who appeared chronically ill. The cervical veins were prominently distended even in the upright position. There was a marked pallor of the exposed mucous membranes. The respirations were rapid and shallow, with an associated periodic congestive type of cough. Dental caries was severe. Examination of the lungs revealed moist râles in both bases, more marked on the left. The heart was normal.

The abdomen was markedly protuberant and comparable in size to that of a full-term gestation. The superficial veins of the abdominal wall were slightly dilated. On palpation, the abdomen was soft and not tender. The spleen was readily palpable. It

occupied the greater part of the abdomen and extended downward into the pelvis. The notch and anterior border were easily outlined, the latter extending into the right lower quadrant. The inferior border could not be defined.

A blood count on the day of admission showed 1,630,000 red blood cells; 3,600 white blood cells, and a normal differential count. Blood smears for the malarial para-



FIG. 2

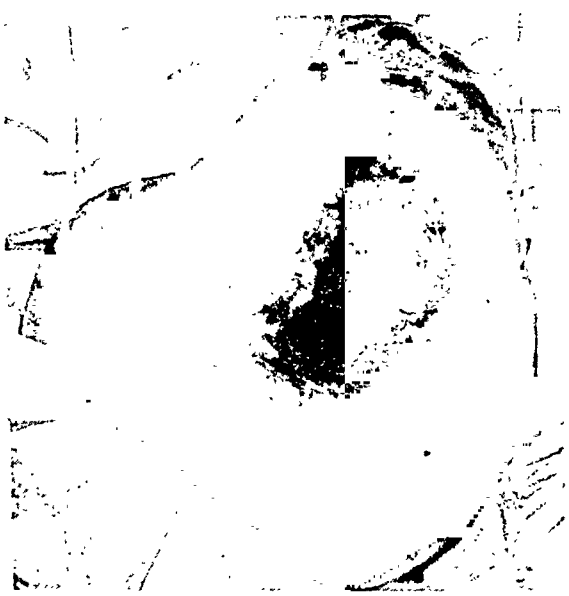


FIG. 3-A



FIG. 3-B

FIG. 2.—The spleen has been mobilized and manually retracted toward the midline. The posterior layer of the lienorenal ligament has been divided and the tail of the pancreas separated from the posterior aspect of the splenic pedicle. This permits the complete exposure of the pedicle posteriorly. (See text)

FIG. 3.—(A). View of the outer surface of the spleen following its removal. The spleen is held in a manner to simulate its position within the abdomen. Note the apical scar.

(B). The under surface of the spleen showing the dilated veins of the pedicle.

site were repeatedly negative inclusive of serial smears taken following the intravenous administration of epinephrine (0.5 cc.). Roentgenograms of the chest were negative. A plain film of the abdomen demonstrated a diffuse and dense shadow which extended throughout the whole of the left side of the abdomen into the right lower quadrant.

FIG. 4.—(A). (A.M.M. Neg. No. 89746) Thickened capsule and dilated capsular vein.
(B). (A.M.M. Neg. No. 89744) Small follicle and congested pulp.
(C). (A.M.M. Neg. No. 89747) Marked dilatation of sinusoids.
(D). (A.M.M. Neg. No. 89745) Few parasitized erythrocytes and phagocytized malarial pigment in single granules and agglutinated masses.

General supportive and symptomatic measures were given. This included a high caloric diet rich in vitamins, iron and vitamin therapy, and strict oral hygiene. The latter embodied the removal of carious teeth. Five hundred cubic centimeters of whole citrated ("stored" or "bank") blood was given on January 16, 1945, and repeated daily for the succeeding four days. The red blood cell count at this time was 2,120,000, an increase of only 490,000 despite the administration of 2,500 cc. of blood. Daily blood transfusions were restarted on the 23rd of January. Two days later the amount was increased to 1,000 cc., and this was administered every other day for the succeeding six days. A total of 8,000 cc. of blood was administered over a period of 16 days, with an increase of only 700,000 in the red blood cell value. (R.B.C. 2,330,000; W.B.C. 4,850.) Despite this lack of a satisfactory increase in the red blood cells a marked improvement in the general condition of the patient had occurred. She was ambulatory daily and her appetite was very much improved.

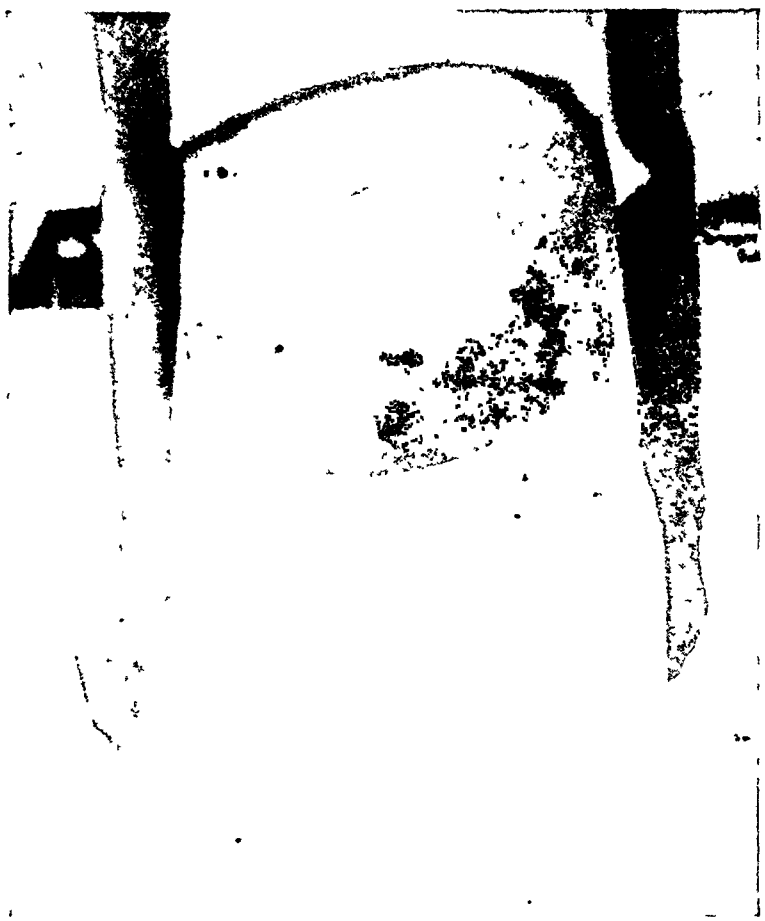


FIG. 5.—Photograph of the patient 13 days following the operation. The incisional scar may be faintly visible.

The operation, originally scheduled for February 2, 1945, was cancelled because of the development of an hyperpyrexia (104° F.). On questioning, it was learned that she had taken her atabrine tablets very irregularly. Active atabrine therapy was immediately started and was followed by a return of the temperature to normal within 48 hours. Despite this she did not appear well and complained of weakness. Her appetite was poor. Examination of the abdomen revealed it to be tense, diffusely tender, and more protuberant than previously noted. Ascites was thought to be present. The liver edge was palpable four finger's breadth below the right costal margin. The liver was not palpable on admission to the hospital. During the succeeding five days a gradual

but progressive improvement occurred. A blood transfusion of 500 cc. was given on two occasions during this period, making a total volume of 9,000 cc. of blood administered prior to operation.

*Operation.*—February 8, 1945: Under closed ether-oxygen anesthesia, a celiotomy was performed through an upper left paramedian incision. There was no free peritoneal fluid and the liver, though enlarged, appeared normal. The spleen was mobilized without difficulty and removed. The veins of the splenic pedicle were enormously dilated, the largest measuring two centimeters in diameter. The wound was closed in layers (silk) without drainage. Five hundred cubic centimeters of fresh whole citrated blood was given during the operation and another 500 cc. upon return to the ward. The spleen weighed 5,450 Gm. (12 pounds), and measured 35 cm. x 25 cm. x 10.6 cm. in size.

*Postoperative Course.*—This was uneventful. The highest temperature recorded was 101.4° F., on the day following operation. Subsequent to the fifth day the temperature maintained a normal level. Blood transfusions (500 cc.) of fresh whole citrated blood were given on the first and third postoperative days. A normal water and salt balance was maintained during the early postoperative period by the parenteral administration of saline and glucose solutions. Sutures were removed on the fifth day. Wound healing was *per primam.* She was allowed out of bed on the tenth day, and discharged from the hospital on the 17th day after operation. Examination at this time showed the liver edge still to be palpable three fingers' breadth below the right costal margin. There was a diminution in the muscle tonus of the abdominal wall, with a mild protrusion of the abdominal viscera. She had no subjective complaints. The objective improvement was marked. A blood count made on the day of discharge revealed 4,110,000 red blood cells; and 8,500 white blood cells, with a normal differential count.

*Pathologic Examination.*—Spleen: (A.M.M. Accession 180365). "The splenic capsule is thickened and hyalinized and there are several torn vascularized fibrous adhesions. The follicles throughout all sections are sparse. Those that are seen are small and composed of small lymphocytes. There is generalized dilatation of the sinusoids. Many of these contain red blood cells and an occasional pigmented macrophage. Others are widely distended and empty. In places the pulp is crowded with phagocytic cells, some contain erythrocytes, others contain single, dark brown, pigment granules. In the region of the greatest dilatation of the sinusoids the Billroth cords are narrow and fibrotic and masses of agglutinated pigment are present. The lining cells of the sinusoids do not contain pigment. Scattered throughout the pulp a small number of red blood cells contain single pigment granules, which on Giemsa stains appear to be malarial plasmodia."

COMMENT.—The lack of an adequate response to the number of blood transfusions given is noteworthy. Eighteen transfusions (9,000 cc.) of whole citrated blood were administered during the three-week period prior to operation. There was an increase in the red blood cell value from 1,630,000 to 3,930,000, an increment of 2.3 million.

The reason for the comparatively meager and slow rise in the number of red blood cells in relation to the number of blood transfusions given, may be related to two factors: (1) The destructive hemolytic action of the spleen; and (2) the use of "stored" or "bank" blood. In reference to the latter, it has been our observation that the clinical response of the patient and the rise in the number of red blood cells do not parallel that obtained when fresh whole blood is used.

The liver was not palpable on admission, a fact which was confirmed by two other examiners. One week prior to operation examination showed the abdomen to be tense and more protuberant. Tenderness was diffuse. The liver edge was palpable four fingers' breadth below the right costal margin. Ascites was believed to be present, but was not confirmed at operation. These findings were associated with abdominal discomfort and an increasing respiratory distress. The changes produced were believed to be the result of a congestion of the portal system secondary to the large volume of blood given.

We are of the opinion that in the preoperative preparation of cases of splenomegaly, blood transfusions should be given in moderation. In the attempt to correct the anemia present enthusiasm may overrule better judgment, particularly when the anemia is refractive to treatment. The clinical response of the patient is a better guide to govern the amount of blood to be administered. If the general condition of the patient is satisfactory the anemia *per se* should not be a contraindication to splenectomy. The elimination of the hemolytic action of the spleen by its removal, and the administration of fresh blood during the operation and in the early postoperative period are more effective in correcting the anemia than the use of large amounts of blood preoperatively. These statements receive confirmation upon review of the case presented.

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# SURGICAL TREATMENT FOR DYSPHAGIA LUSORIA

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DYSPHAGIA LUSORIA has long been recognized as impairment of swallowing which occurs when a right subclavian artery arises abnormally from the left side of the aortic arch and then passes behind or in front of the esophagus and thereby compresses the esophageal tube. As early as 1794, Bayford[1] nicely described such an anomalous subclavian artery can exist without making itself manifest; it may be incidentally discovered at a postmortem examination. In other individuals it produces symptoms which are mild, and of little consequence. In occasional patients the disturbance in swallowing may be severe enough to interfere seriously with the individual's health or nutrition. Dysphagia is most apt to appear or to be aggravated (1) when the artery is taut and stretches across the esophagus like a bow-string; (2) when the vessel becomes sclerotic and less elastic in the latter part of life; or (3) when there is aneurysmal dilatation of the artery. The detection of the anomaly by roentgenological studies has been recently discussed by Copleman.[2] So far as I am aware, the following case is the first in which surgical division of such an anomalous vessel has been attempted.

**Case Report.**—J. R., a four-month-old baby, was referred to the hospital, November 14, 1945, by Dr. Joseph F. Gibbons, because of difficulty in feeding. At about four weeks of age it was first noticed that the child had discomfort or pain while nursing. During the act of deglutition, a little of the milk would be swallowed without hesitation, but the baby would then become fretful or would cry; following this he would either refuse to take more of the feeding, or would take it only under protest. Sometimes, six or eight ounces of the mixture would be ingested without much trouble, but on most occasions there was obviously something wrong after an ounce or two had been swallowed, and the child would "stiffen up with pain." There was occasional regurgitation of uncurdled milk, but there was no projectile vomiting. Several changes of formula were made without apparent benefit. At about four months of age, cereal was offered; this was taken eagerly in small amounts, but after it the baby would always refuse milk for several hours. In spite of these difficulties the weight-gain had been satisfactory, yet it was obvious that this state of affairs had depended upon an intelligent and attentive mother who had discovered that an adequate amount of milk mixture could be given to the baby by offering 15 to 20 small feedings through the day.

*Physical Examination:* The child appeared to be healthy. He weighed 16 pounds, 2 ounces. There were no important variations from the normal in the abdomen or chest. The baby was alert, and there was no reason to suspect central nervous system disease or birth injury.

*Course:* Roentgenologic examination in the lateral projection, after ingestion of a thin barium mixture, showed an indentation of the posterior wall of the esophagus at the level of the third thoracic vertebra. When viewed anteroposteriorly, this filling de-

fect lay in an oblique direction, and suggested that there was an elongated, narrow structure which ran upward and to the right between the vertebral column and the esophagus. Some of the films showed air in the entire trachea; this was not displaced, distorted, or compressed in any way. The roentgenologic findings were interpreted by Dr. Edward Neuhauser as representing an anomalous right subclavian artery, which arose from the left side of the aortic arch and then ran upward and to the right behind the esophagus so that this tube was compressed along its posterior wall.

The child was observed on the ward for 12 days. On some occasions the baby would take an entire feeding of six or eight ounces in a reasonably satisfactory manner.

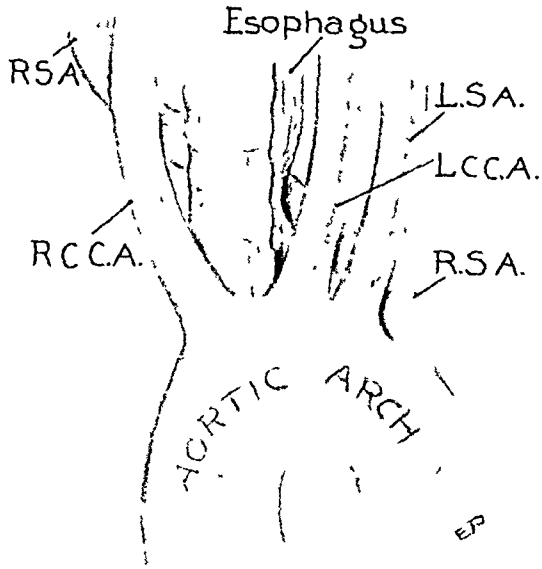



FIG. 1.—Drawing of anatomic arrangement found at operation. The anomalous right subclavian artery compresses the posterior wall of the esophagus. L. C. C. A.—Left common carotid artery. L. S. A.—Left subclavian artery. R. C. C. A.—Right common carotid artery. R. S. A.—Right subclavian artery.

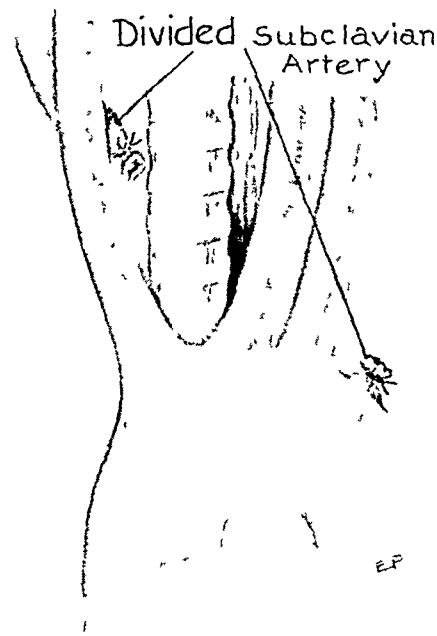



FIG. 2.—Surgical procedure. Esophageal compression has been relieved by dividing the right subclavian artery.

At other times, he would swallow only an ounce or two, would cry, and then refuse to take more. Through the first week, there was a weight loss of 14 ounces, but during the second week the child was urged much more during feedings and the weight rose again to the admission figure. From the history and hospital course it was obvious that the child's life was not endangered by the esophageal obstruction, and, indeed, the baby could be kept in a satisfactory state of nutrition with the existing intrathoracic abnormality. However, it was also clear that the difficulties in feeding were considerable, and it was reasonable to believe that the symptoms could be alleviated if the anomalous vessel were divided and the esophagus freed.

*Operation.*—November 26, 1945: Under cyclopropane anesthesia, with a tightly fitting face mask, and without an intratracheal catheter, anterolateral approach was made through the left side of the chest, entering the pleural cavity through the third interspace. The third and second costal cartilages were divided. This gave an excellent exposure of the mediastinum. The aortic arch lay in a normal position. The thymus

was partially dissected away and exposure was gained toward the patient's right so that the entire arch and its various branches could be adequately viewed (Fig. 1). The right subclavian artery arose in an anomalous fashion from the posterior aspect of the left side of the aortic arch and then coursed upward and to the right behind the esophagus, the posterior wall of which was indented. Between this anomalous artery and the vertebral column the thoracic duct was clearly visible and could be left undisturbed during the subsequent dissection. The right subclavian artery was extensively liberated from its bed and was then doubly ligated and divided near the aortic arch. The distal portion of the artery was permitted to retract to the patient's right and beyond the esophagus (Fig. 2). The lung was completely reexpanded and the chest appropriately closed. I did not hesitate in dividing the first portion of the subclavian artery, since it was assumed that there would be branches from the second and third parts of the vessel for maintenance of an adequate circulation in the right arm.

*Postoperative Observations:* Following operation the baby had an extremely satisfactory convalescence. For the first 36 hours oral fluid was given in limited amounts, but after this a full formula was used. Feedings were offered on a four-hourly schedule, and were taken without hesitation. The wound healed *per primam.* At the completion of operation no radial pulsation could be detected, but a faint beat could be felt in the right axillary artery. At the time of hospital discharge, frequent but irregular pulsations could be felt at the wrist. Accurate skin temperature readings were not made, but at all times the right hand and arm felt as warm as the left. The baby was discharged from the hospital in a very satisfactory state on the tenth postoperative day.

When last seen, January 7, 1946, the baby had had no trouble in swallowing, and had gained to 18 pounds, 6 ounces. Barium examination of the esophagus showed it to be normal. The right hand and arm were warm, moved normally, and were pink. The right radial pulse could not be accurately counted, but frequent beats could be felt.

The favorable outcome in this case certainly suggests that dysphagia lusoria can be treated by surgical means. An anomalous subclavian artery does not always produce symptoms, but when it does so, any pressure on the esophagus can be abolished by the procedure which is here described. The intrathoracic part of the subclavian artery can be divided with impunity because the second and third portions of the vessel have collateral channels which are sufficient to maintain a satisfactory flow of blood to the arm.

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# PULMONARY ACTINOMYCOSIS

## ITS TREATMENT BY PULMONARY RESECTION IN CONJUNCTION WITH CHEMOTHERAPY

### REPORT OF TWO CASES

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PATIENTS with pulmonary actinomycosis present a challenge to therapeutic measures. In a series of 1,330 patients with actinomycosis, collected by Cope,[1] the thorax was involved in 15 per cent. The results of treatment employing such time-honored measures as potassium iodide, thymol, vaccines, and roentgen rays, have, in general, proved unsatisfactory. With the advent of the sulfonamides, encouraging results were reported[2-12] in a number of patients having cervicofacial, thoracic, and abdominal actinomycosis, particularly when sulfathiazol and sulfadiazine were employed. However, many patients were refractory, or had only temporary improvement under this form of therapy.

Because of the reported[13] bacteriostatic effect of penicillin on actinomycosis, this agent has been employed clinically with encouraging results.[14,15,16] Although sulfonamides and penicillin have been of value in the treatment of actinomycosis, many authors conclude that the most successful results will be obtained when chemotherapy is used in conjunction with surgical measures.

Pulmonary actinomycosis is probably secondary to aspiration of the infected material from the mouth,[17,18] for these organisms are normally harbored about carious teeth and tonsillar crypts. A pneumonic process results, characterized by suppuration and fibrosis. Burrowing of one abscess to another is commonly seen. The infection usually involves the pleura and eventually results in multiple thoracic sinuses. The disease may be either unilateral or bilateral. Microscopically, a highly vascular granulation tissue is found characterized by areas of suppuration and fibrosis. Giant cells are frequently seen. A diagnosis can be established only by finding the actinomycotic granules.

The clinical course is that of a debilitating disease. The patients may give a long history of pulmonary suppuration when first seen. The disease is characterized by periods of remission and exacerbation. During the periods of remission, there is a low-grade fever, a productive cough, expectoration that may be bloody, and pleural pain. There is a progressive loss of weight and strength. In the two patients to be presented, periods of exacerbation occurred every six to ten weeks, associated with evidence of increased toxicity; a spiking fever to 104°F. daily, an increase in sputum, pleural pain and evidence of extension of the disease, roentgenologically. The clinical diagnosis rests upon identifying the organism, preferably from exudate obtained bronchoscopically, to prevent contamination, otherwise from

mouth content. Nothing specific is noted roentgenologically. The roentgenograms show extensive areas of suppuration and pneumonitis. In the later stages evidence of osteomyelitis involving the ribs may be seen. It must be differentiated clinically from tuberculosis, other fungous infections, and pyogenic suppurative disease.

The case histories to be presented are reported because of their interest from the standpoint of therapy. Both patients suffered from the progressive pulmonary suppuration for more than a year. The onset in one was insidious, while in the other it followed extraction of teeth. The disease appeared progressive and refractory to more than adequate treatment with sulfadiazine and penicillin, used both alone and in combination, almost constantly over a period of a year. At one time, in addition to the above, potassium iodide or thymol was also employed. Except for decreasing the evidence of toxicity during the periods of exacerbation, these chemotherapeutic measures appeared to be of no permanent value. Because of the failure to improve after this period of time, pulmonary resection was resorted to, with apparent success. In the first patient, the diagnosis was suspected but not proved until microscopic verification of the pathologic sections postoperatively, and identification of the organism by culture. Because of the excellent results obtained in the first patient by pulmonary resection, operation in the second patient was advised after he had failed to improve on chemotherapy.

As in tuberculosis, the disease is usually more extensive than is noted roentgenologically. If, in patients with unilateral pulmonary actinomycosis unrelieved by chemotherapeutic measures, pulmonary resection is resorted to, total pneumonectomy should probably be undertaken rather than partial resection, if there is any question as to the extent of the disease. The pulmonary involvement in both of the patients to be presented was found to be considerably more extensive at the time of operation than was apparent preoperatively. The interlobar fissures and pleural surfaces were completely obliterated by pleural involvement, necessitating dissection in the extrapleural plane in several places. Burrowing of the abscesses across the longitudinal fissure was present. In the first patient, a left pneumonectomy was performed, with success. In the second patient, a right upper lobe lobectomy and segmental resection of the dorsal segment of the right lower lobe was undertaken. In this case there was an immediate recurrence of the disease in the remaining portion of the lower lobe, requiring removal of this and the middle lobe. With the extensive pleural adhesions, the likelihood of entering abscesses during the dissection and further contaminating the pleura is great. With the lung removed, a high concentration of penicillin and sulfadiazine can be maintained in the pleural space to combat this contamination, which would not be possible following partial pulmonary resection because of the desire for early reëxpansion of the residual lung tissue and obliteration of the pleural space.

## CASE HISTORIES

**Case 1.**—The patient, a 19-year-old white male, developed a "chest cold" in December, 1943, characterized by bloody sputum, a temperature elevation to 101°F., and pain in his left chest. Roentgenograms showed evidence of pneumonitis lateral to the left hilus. The white blood count at that time was 7,200. By January 15, 1945, the cough was productive of three ounces of bloody sputum daily. Cavitation was noted roentgenologically at the previous site of pneumonitis (Fig. 1A). All bacteriologic studies for tuberculosis were negative. The tuberculin test was positive; and the coccidiodin skin test was negative. Microscopic examination of the sputum showed *hemolytic Streptococci, Staphylococcus aureus, Streptococcus viridans,* and *micro-catarrhalis.* The clinical course was characterized by remissions and relapses, with increasing debility. An increase in toxicity, cough and sputum was noted May 1, 1944. There was also an increase in the pneumonitis in the lower lung field roentgenologically. The temperature ranged from 102° to 104°F. daily. The sedimentation rate was 56 millimeters per hour. Sulfadiazine was given between May 10, 1944 and May 24, 1944; with a blood level ranging between 13 and 15 milligrams per cent. No apparent improvement was noted, so the sulfadiazine was discontinued and intramuscular penicillin was begun (a dosage of 30,000 units every three hours). This was continued for five weeks for a total dosage of 8,500,000 units. During this period of time there was considerable symptomatic improvement — the temperature became normal, and the appetite and weight increased. The pneumonitis and suppuration, as demonstrated by roentgenograms, showed some extension in spite of the symptomatic improvement. The sedimentation rate decreased to 11 millimeters in an hour. This remission lasted until August 1, 1944, when there was a recurrence of symptoms. The temperature ranged between 102° to 104°F. The sedimentation rate increased to 54 millimeters per hour. Sulfadiazine was again given for two weeks, with the blood level being maintained at 11 milligrams per cent. The white blood count varied between 13,000 and 18,000. Only the usual organisms were found on culture. Fungous studies were not made. A similar episode was noted again in September. A third course of sulfadiazine was given between September 23, 1944 and October 23, 1944. At this time, because of failure to improve, and because the disease was progressing clinically and roentgenologically (Fig. 1B), in spite of repeated adequate courses of chemotherapy, the patient was transferred to Kennedy General Hospital for further treatment.

He had lost 30 pounds in weight. All laboratory procedures were repeated, with similar findings. Bronchoscopic examination was performed November 25, 1944. Considerable purulent, foul smelling exudate was noted coming from both the upper and lower lobe bronchial orifices. Fungous infection was suspected from the clinical course, and cultures for fungi were planted. During the next three months there were two more severe exacerbations. Upon one occasion the white blood count increased to 38,000. Sulfadiazine and penicillin were given, both alone and in combination in adequate doses, almost continually. They appeared most effective when used in combination. The total dosage of penicillin during this period was 5,940,000 units. In spite of all therapeutic measures, this patient continued to fail. The cough became almost constant, and was productive of over four ounces of bloody sputum daily. Roentgenologically, the suppurative process appeared to involve the lower two-thirds of the left lung (Fig. 1C). On February 3, 1945, bronchoscopic examination was repeated, with findings similar to those previously noted. Because of the progression of the disease and its failure to respond to chemotherapy, a pneumonectomy was performed February 12, 1945.

At operation, the inflammatory process appeared to involve the entire lung except for the apex. The longitudinal fissure was not distinguishable because of the infection. The pleural surfaces were edematous in many places, and in others so united by inflammation that separation was unusually difficult, necessitating, in several regions, the

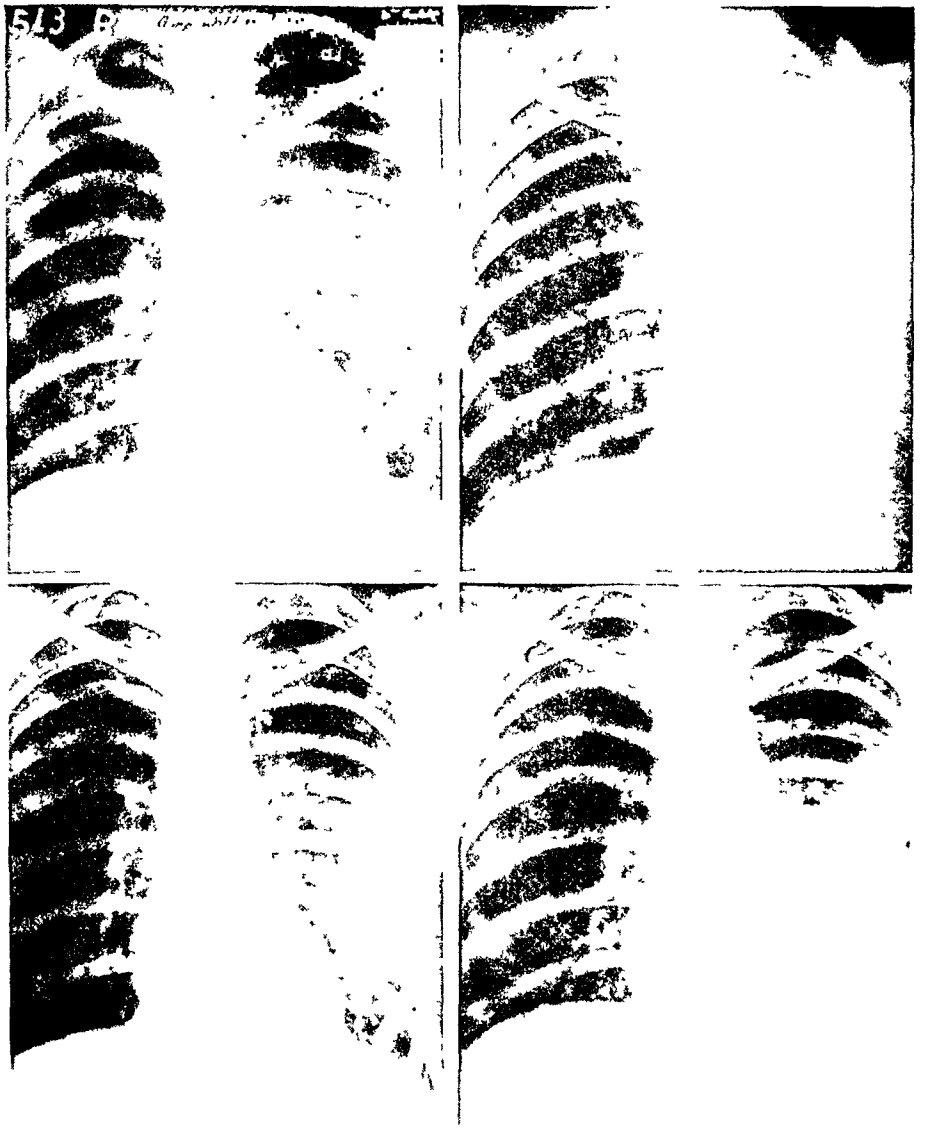



FIG. 1.—Case 1: Serial roentgenograms of a patient with pulmonary actinomycosis, demonstrating the progression of the infection over a period of one year, in spite of adequate treatment with both sulfadiazine and penicillin during this period of time.

(A) Roentgenograms taken January 24, 1944, one month following onset of illness, demonstrating cavitation in the midportion of the left lung.

(B) Roentgenograms taken November 2, 1944, demonstrating an extension of the pulmonary suppuration.

(C) Roentgenograms taken February 10, 1945, demonstrating further extension of the pulmonary suppuration while taking both sulfadiazine and penicillin. Residual lipiodol can be noted in the lower lobe of the right lung

(D) Roentgenograms taken two months following pneumonectomy, February 12, 1945.

use of the extrapleural plane. At one point a pulmonary abscess was opened, with some contamination of the pleura. The lung was hard and firm, having the consistency of liver. The hilar structures appeared less involved and their dissection was not particularly difficult. The day following operation, and for the next several days, cultures from the previous bronchoscopic and sputum specimens were reported showing the presence of *Actinomyces bovis*. The pathologic examination of the lung showed extensive areas of suppuration and consolidation. There were multiple minute abscesses. The granulation tissue was particularly vascular and the actinomycotic colonies were demonstrated. Because of the demonstration of actinomycosis, and the presence of contamination at the time of the pneumonectomy, a combination of penicillin and sulfadiazine was given both systemically and intrapleurally for a period of ten days. The daily systemic dosage was four grams of sulfadiazine and 200,000 units of penicillin. The daily intrapleural dosage was four grams of sulfadiazine and 100,000 units of penicillin. Pleural fluid developed rapidly, and in large amounts, requiring the daily aspiration of 500 to 800 cc. for a period of a week, in order to maintain the mediastinum in the midline.

The patient's postoperative course was otherwise uneventful. A letter from the patient six months postoperatively stated that he was in good health. It is too soon to make any definite statement, but the prognosis appears to be good.

COMMENT.—This patient serves to illustrate the chronicity of pulmonary actinomycosis, and its possible resistance to therapy. In all such cases, fungous infection should be suspected and the proper examinations made. In this particular instance, the actinomyces were unusually slow in growing culturally. The value of pulmonary resection when other therapeutic measures have failed is also demonstrated. It is felt that both sulfadiazine and penicillin, used in large dosage postoperatively, are a valuable adjunct to the surgical procedure.

**Case 2.**—The patient, a 24-year-old colored male, had a number of teeth extracted in May, 1944. During the following month he noted a cough, productive of bloody sputum. The temperature during the first month of his illness ranged from 101° to 102°F. The white blood count varied between 14,000 and 23,000. Roentgenologic studies showed evidence of pneumonitis, with areas of rarefaction in the apex of the right upper lobe. The patient was thoroughly studied for tuberculosis, but all studies were negative. Several sputum examinations were suggestive of fungous infection, but no fungus was identified. The patient was treated with sulfadiazine, and a blood level of ten milligrams was maintained. After one month he felt somewhat improved, and the sulfadiazine was discontinued. In spite of the symptomatic improvement, the temperature during August ranged between 99° and 100°F. Roentgenograms showed no improvement. During the next several weeks the sputum and cough gradually increased. The patient noticed considerable pain in the right chest, particularly on inspiration. Intramuscular penicillin was then administered for a month (25,000 units every three hours, for a total dosage of 6,000,000 units). Because of the suggestive evidence of fungi, potassium iodide was given. Following this therapy, there was again a remission, but as before there was no appreciable change in the disease noted in the right lung field, so the patient was again placed on sulfadiazine, four grams a day, and maintained on this dosage until admitted to Kennedy General Hospital in November, 1944. Admission roentgenograms showed considerable improvement, and, symptomatically, the patient was better. He was bronchoscoped November 25, 1944. The right upper lobe orifice was hyperemic and granular. A foul-smelling exudate escaped from this orifice, from which a culture was taken. This, later, showed *Actinomyces*. This remission lasted until the

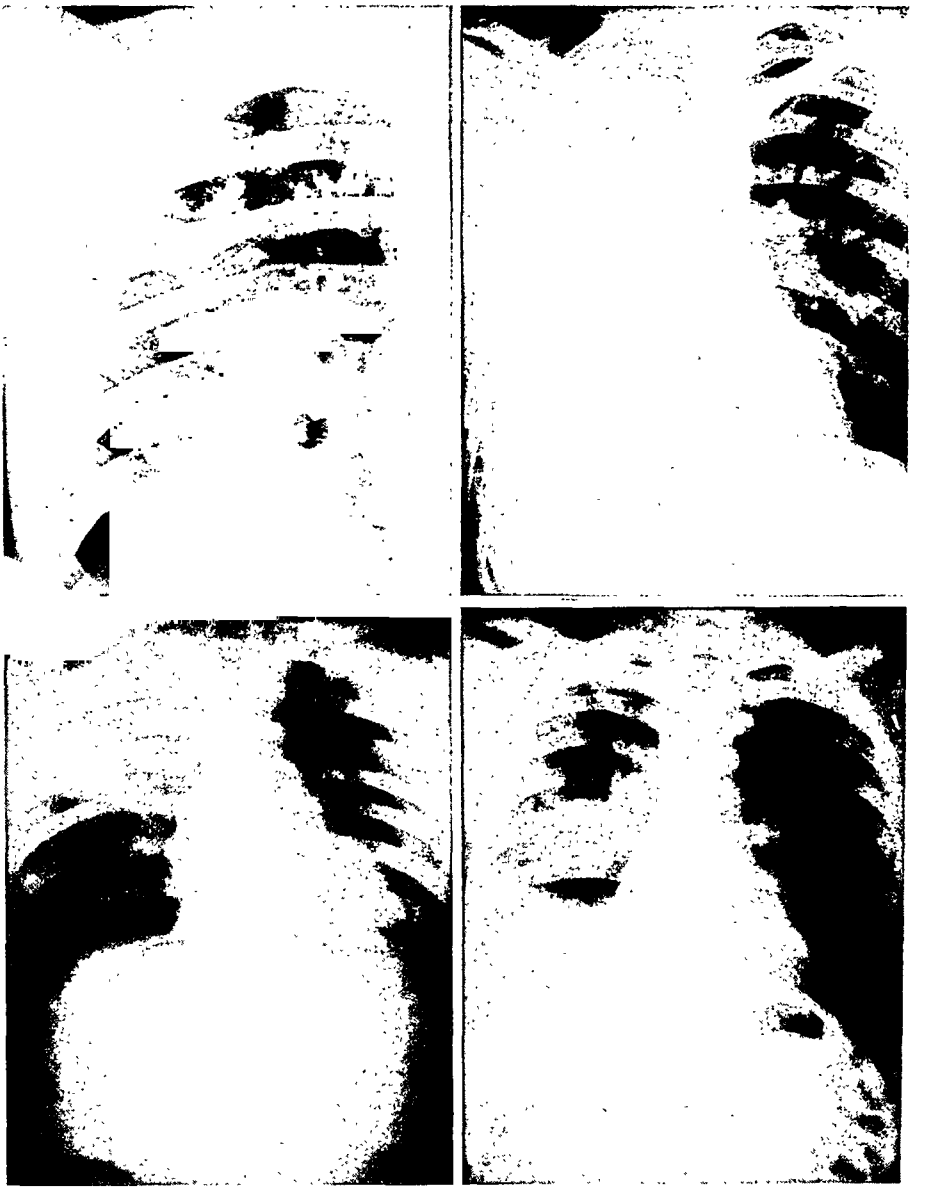



FIG. 2.—Case 2: Serial roentgenograms of a patient with pulmonary actinomycosis demonstrating the progression of the infection over a period of a year, in spite of adequate treatment with sulfadiazine and penicillin.

(A) Roentgenograms taken December 10, 1944, demonstrating pulmonary actinomycosis in the apex of the right lung.

(B) Roentgenograms taken February 26, 1945, during an exacerbation demonstrating some atelectasis as well as pneumonitis in the upper lobe of the right lung.

(C) Roentgenograms taken five weeks after a right upper lobe lobectomy and segmental resection of the dorsal lobe area of the right lower lobe demonstrating a recurrence of the actinomycosis in the basal segment of the lower lobe.

(D) Roentgenograms taken two months following completion of the pneumonectomy, on May 14, 1945.

middle of December, at which time all of the previous symptoms became aggravated, and the roentgenograms showed an increase in infiltration in the right upper lobe (Fig. 2A). Sputum studies revealed the presence of *Actinomyces bovis* in large numbers on direct smear examination and by culturing.

On December 10, 1944, four grams of sulfadiazine a day was again given. There was no significant benefit after 20 days, so intramuscular penicillin (25,000 units every three hours) and increasing amounts of potassium iodide were given, in addition to the sulfadiazine, for a period of three weeks. This therapy was discontinued for two weeks and then begun again on January 23, 1945, and continued for another three weeks—a total of 8,000,000 units of penicillin having been given. There was only

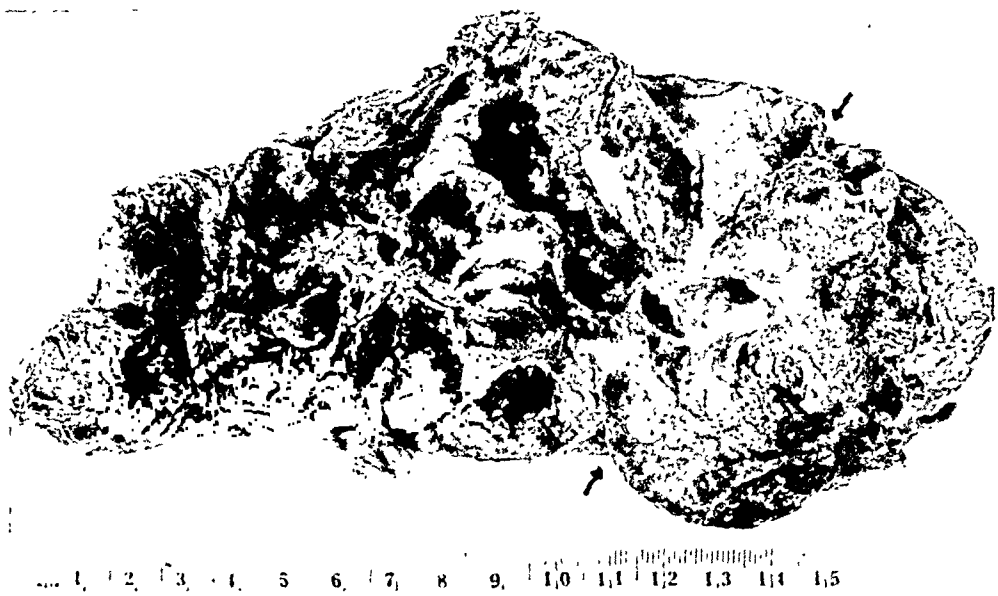


FIG. 3.—Case 2: Surgical specimen of the right upper lobe and dorsal segment of the right lower lobe, demonstrating the multiple abscesses and sinuses. Arrows designate the longitudinal fissure.

moderate symptomatic improvement. The patient was again bronchoscoped January 20, 1945, and similar findings were noted. Roentgenologically, there appeared more localization of the disease process in the right upper lobe. Within two weeks of discontinuing the chemotherapy, the patient became acutely ill. The sputum increased to four to five ounces daily, and was very foul-smelling, and bloody. The temperature spiked to 104° to 105°F. daily. There was severe pleural pain. Penicillin and sulfadiazine were given, in dosages as above, but the patient remained acutely ill for about ten days. The roentgenograms during this period of time showed an extension of the pneumonic process, with some evidence of atelectasis in the right upper lobe (Fig. 2B).

For the next month there was some improvement symptomatically and roentgenologically. During this time he continued to get both sulfadiazine and penicillin. However, it became apparent that chemotherapy alone could not hope to cure this patient. In view of the apparent excellent results by pulmonary resection in the previous patient with pulmonary actinomycosis, it was felt that a permanent cure could be attained in this patient only by operative therapy, in combination with chemotherapy. Because of the diffuse nature of the disease and the type of infection present, operative therapy by pulmonary resection, rather than drainage, appeared to be the procedure of choice. Roentgenologically, the disease appeared confined to the right upper lobe, so resection of this lobe was contemplated. On April 5, 1945, the patient was explored.

As in Case 1, the disease was considerably more extensive than indicated roentgenologically. The pleural surfaces were edematous in some places, while in other areas they were exceedingly adherent as a result of inflammation and fibrosis. This made dissection considerably more difficult. The upper lobe was hard and indurated. Several areas of fluctuation could be palpated. The longitudinal fissure was obliterated posteriorly by what appeared to be an abscess in the base of the upper lobe communicating with a similar one in the dorsal segment of the lower lobe. The basal segment of the lower lobe and middle lobe appeared normal. An upper lobe lobectomy and segmental resection of the dorsal segment of the lower lobe was performed as a unit. Ten grams of sulfadiazine and 200,000 units of penicillin were placed in the pleural space prior to closing.

Pathologic examination of the resected pulmonary tissue showed multiple gangrenous abscess cavities, as noted in Figure 3, with sinuses burrowing from one abscess to another. The walls of the abscesses were both necrotic and fibrotic in areas. There was an hemorrhagic exudate in which the sulfur granules were easily demonstrated. Microscopically, the granulation tissue was extremely vascular and densely packed with plasma cells. The patient was treated postoperatively with six grams of sulfadiazine and 400,000 units of penicillin (intramuscularly) daily in divided doses.

The postoperative course was relatively uneventful with early reëxpansion of the residual lung tissue and obliteration of the pleural space. However, in approximately two weeks time, the sputum increased, and was again found to contain *Actinomyces.* There was a daily elevation of the temperature to 100° to 101°F. Serial roentgenograms during the next four weeks showed increasing infiltration in the basal segment of the residual lower lobe as shown in Figure 2C. It was felt that this represented a recurrence of the actinomycosis, in spite of the massive dosage of chemotherapy the patient was still receiving. Consequently, on May 14, 1945, the remaining portions of the lower lobe and middle lobe were removed. The pleural surfaces noted at the second operation were similar to those originally. Technically, the operation was no more difficult. Five grams of sulfadiazine and 200,000 units of penicillin were again placed in the pleural space prior to closing. Pathologic examination of the lower lobe confirmed the recurrence of the actinomycotic process. Postoperatively, the patient was treated with sulfadiazine and penicillin, administered both systemically and intrapleurally, as in the first patient. It was also necessary to aspirate approximately 500 cc. of fluid daily for ten days to maintain the mediastinum in the midline. Intrapleural chemotherapy was continued for two weeks. The patient's postoperative course was entirely uneventful. A check-up examination over a year postoperatively showed the patient to be well.

DISCUSSION.—This patient illustrates a number of interesting features. The first is the periodicity of the relapses and remissions. Chemotherapy was of considerable value during the periods of exacerbation but did not appear to significantly influence the course of the disease, as a whole. In spite of intensive chemotherapy the disease was progressive. It became apparent that chemotherapy, alone, could not cure this patient — so pulmonary resection was resorted to. It is interesting to note that the extent of the disease process was also greater than suggested by roentgenograms preoperatively. It was instructive to us to find that segmental resection is unwise in such infections because of the inability to detect grossly, or roentgenologically, the entire extent of the disease. In case of any doubt total pneumonectomy should be performed. The other advantages of pneumonectomy are described.

## SUMMARY AND CONCLUSIONS

Two case histories of patients with pulmonary actinomycosis are presented. Both patients were treated with intensive courses of sulfadiazine and penicillin therapy, used both alone and in combination, almost continuously, over a period of one year. This therapy appeared to be of value only during the periods of exacerbation and had no permanent effect upon the progress of the disease, as a whole. After a year's therapy in both patients without significant benefit, apparent successful results were attained following pneumonectomy. During the postoperative period intensive therapy, employing sulfadiazine and penicillin both systemically and intrapleurally, was used. It is felt that patients with pulmonary actinomycosis who fail to improve upon intensive, adequate courses of chemotherapy should be treated by pulmonary resection while the disease is still limited to the lung and before the development of multiple thoracic sinuses.

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# MANAGEMENT OF INJURIES TO STENSEN'S DUCT

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It is a generally accepted fact that surgery for repair of lacerations or injuries of Stensen's duct has been notoriously unsuccessful. All too often, it results in complete failure. Despite this gloomy prognosis, occasional cases of successful immediate repair have been reported, but few, indeed, are the reports of success in the treatment of the more chronic types of fistulae.

There are several reasons for this state of affairs. The injury is so rare that no one individual has acquired any considerable experience in this field. There are inherent difficulties in the peculiar anatomy and relations of Stensen's duct which make surgery hazardous. Although many of the operations and procedures described are excellent in principle, none are complete. Furthermore, a comprehensive pre- and postoperative regimen has never been published.

The authors have been fortunate enough to have encountered a number of duct injuries while on duty at an Army General Hospital during the years 1943, 1944 and 1945; and, as a result of this experience, an operation and general system of care for these cases have been developed. No claim of originality is made; the operation has been described in principle by Tees,[1] Glascock,[2] and others.[3-7] It is felt, however, that the complete and detailed description of the care of these cases represents a contribution worthy of publication, inasmuch as a cure in every case, even fistulae of prolonged duration, was accomplished in the series herein reported.

## ANATOMY

Stensen's duct is formed by the convergence of several branch-duct tributaries within the substance of the gland. It leaves the anterior border of the gland at its most prominent part to run forward in an horizontal direction across the masseter muscle below the accessory parotid gland. It is accompanied by branches of the facial nerve and the transverse facial artery which are commonly some distance above it, though this relationship is variable. At the anterior border of the masseter it passes abruptly inward, piercing the pad of fat and buccinator muscle; then forward for five to ten millimeters to emerge through a narrowed orifice in the papilla opposite the second upper molar tooth. Its course is rather constant. It can be marked by a line extending from the inferior border of the external acoustic

meatus to a point midway between the ala of the nose and the upper border of the upper lip. The duct measures on an average of six to seven centimeters in length and four to five millimeters in diameter, but at the orifice it narrows to a point where it admits only a fine bristle. The walls are fibrous, thick and resistant and do not collapse. The fibrous coat contains contractile tissue which ejects saliva during mastication. The duct is lined by mucous membrance of short columnar epithelium.

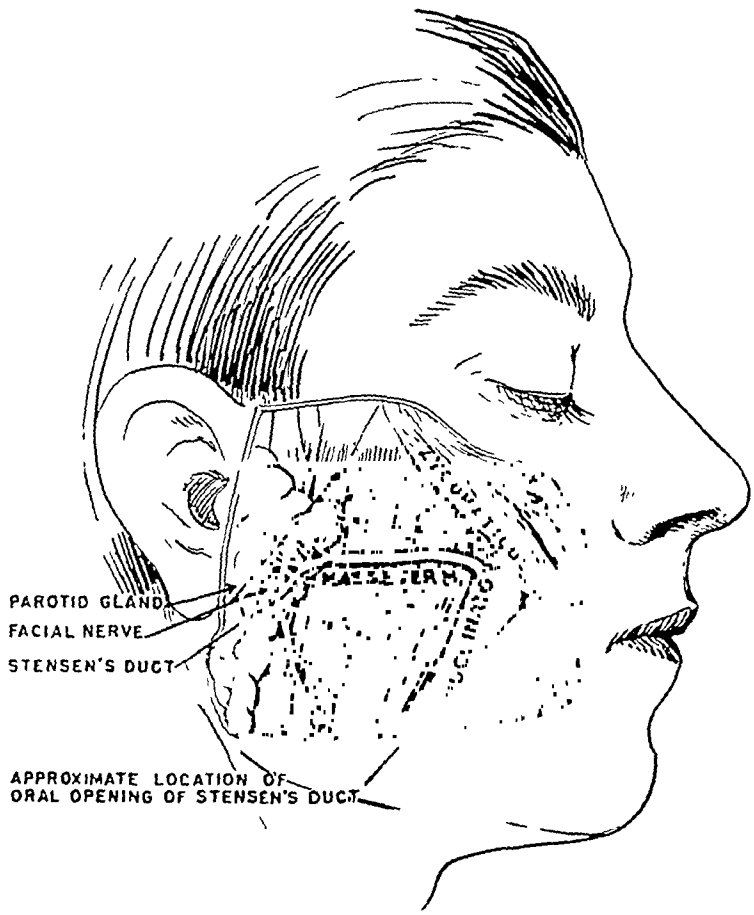



FIG. 1.—Anatomic sketch illustrating the relationship of Stensen's duct to the surrounding structures. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

The papilla is a complex mechanism which functions both as a sphincter and a valve. The contraction of elastic tissue holds back the saliva, for the most part; during mastication, relaxation occurs and allows the saliva to enter the mouth. This illustrates the sphincteric action. The valve is formed by a sharp angulation of the duct as it approaches the buccal surface of the papilla. This is easily demonstrated during the dilation and probing. The function of the valve is to prevent the contents of the mouth from gaining entrance to the duct.

### TREATMENT

Treatment of parotid duct fistulae, and injuries, may be conveniently divided into three categories depending upon the anatomic location: 1. Fis-

FIG. 2.—The end result of spontaneous healing following severe injury to Stensen's duct. The injured portion of the duct is embedded in a mass of scar tissue with the lumen of a portion of the distal segment obliterated by the cicatrix. The proximal segment is patent and is secreting saliva. This condition prevailed in Cases 2 and 3. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)



FIG. 3.—The intra-oral and the external probes are in position. The mass of scar tissue and the cicatrixed portion of the distal segment have been excised. The metal dilators drawn to scale, are shown in the lower right hand corner. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

tulae in the glandular area. 2. Fistulae over the masseter muscle. 3. Fistulae anterior to the masseter muscle, or in the buccinator muscle area.

1. *Fistulae in the Glandular Area:* These, if connected with the main duct or a main branch tributary, are best treated by surgery (as described below). If they arise from minor tributaries, however, a number of methods may be employed. (a) Spontaneous healing: This occurs rather frequently if the tributary duct communicating with the fistula is small. As a rule,

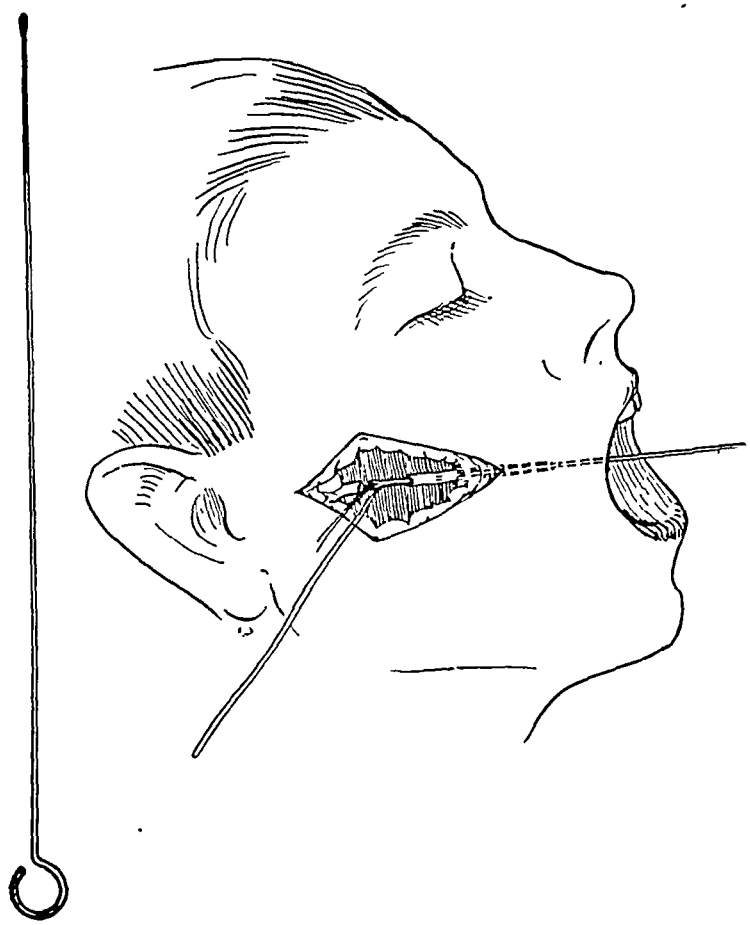


FIG. 4.—The intra-oral probe after being passed through the distal segment is threaded with the tantalum wire. The probe used is illustrated here. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

infection of the acini supplying this minor duct occurs, followed by atrophy or disintegration with cessation of secretion, or the fistulous tract becomes occluded by a constricting cicatrix. Moreover, mechanical occlusion of the main duct or any of its tributaries is followed by atrophy of the supplying acini.[2] (b) Cauterization: Chemical cauterization with silver nitrate, phenol or actual cautery has been recommended. Roentgenotherapy has been found quite successful in the treatment of minor glandular fistulae. (c) Excision of the gland: This is an extremely difficult operation; a procedure of this magnitude would be unjustified in minor fistulae. There are better methods of treatment for fistulae connected with the main duct.[8] (d) Avulsion of nerves:[9] Avulsion of the auriculotemperal nerve has been advocated. This

FIG. 6.—The twisted tantalum wire is in its correct position. It occupies the lumen of the proximal and distal segments of the duct and the gap between these segments. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)



FIG. 5.—The twisted tantalum wire has been drawn through the distal duct segment and is now being inserted into the proximal segment. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

procedure, or section of the glossopharyngeal nerve itself, will eventually bring about acinar inactivity and, therefore, should result in a cure. Such procedures are too radical because cures may be effected by less involved methods. Thus, there are three choices in the treatment of glandular fistulae other than by surgery: Allow a reasonable time to pass in the hope of spontaneous healing. Try cauterization by chemical or actual cautery. Destroy the function of secretion by roentgenotherapy.

2. *Fistulae over the Masseter Muscle:* Although no figures are available and no reported series is large enough from which to draw any conclusions, a study of the anatomy and search of the literature suggests this to be the



FIG. 7.—Case 1: Preoperative lipiodol study showing that both proximal and distal segments of the left parotid duct are patent. There is a normal distribution of the lipiodol throughout the acini of the gland. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

most frequent site of traumatic fistula. The duct is relatively superficial; in some individuals it can be palpated against the tensed masseter. If the laceration is recent, it should be sutured immediately using the technic described below. A fistula of months', even of years', duration does not contraindicate surgery, however. One of our cases had had a fistula for 14 months, yet it responded to surgery promptly. Brown, Kuttner, and Crouse have described operations in this region using buccal mucous membrane flaps to create a duct which is then attached to the proximal segment.[8] Such procedures may succeed but are, in the opinion of the authors, unnecessarily complicated and involved.

3. *Fistulae Anterior to the Masseter Muscle or in the Buccinator Muscle Area:* Fistulae in this area seem to be rare. They may be repaired by several operations which depend upon the conversion of the external fistula

into an internal, or oral one. Such operations have been described by von Langenbeck, DeGuise, Kaufman, and others.[8] All of these operations have the same fault. They short-circuit the distal end of the duct and the duct papilla. Thus, the duct papilla with its valve-like action is lost, and there is no bar to ascending infection which promptly results. Two of our cases illustrate this point. (Cases 4 and 5.) In view of this experience, the authors feel it is essential that the papilla be preserved because of its pro-



FIG 8—Case 2: Lipiodol was first injected through the oral opening of the right parotid duct and resulted in a wide spread of the lipiodol into the soft tissues of the face. An attempt was then made to instill lipiodol into both distal and proximal segments externally through the fistulous opening. This resulted in failure to visualize the distal segment. The proximal segment is clearly outlined. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

tective action. This is accomplished in the operation recommended by the authors.

### OPERATIVE PROCEDURE

(A) *Prior to Surgery:* The following steps should be carried out:

1. Lipiodol should be injected into the fistula, and into the oral opening. A study of the resulting radiographs will frequently give much valuable information.

2. For a period of approximately ten days, the oral opening in the papilla should be dilated daily, and the duct probed as far as possible with flexible graduated probes.

3. Twenty-five thousand units of penicillin should be administered intramuscularly every three hours beginning 24 hours before surgery.

(B) *Surgery:* Intratracheal anesthesia is ideal. The throat can be blocked off and the operation, which requires an intra-oral field as well as an external field over the cheek area, can proceed unhampered.

Step I: The opening in the papilla is dilated and a flexible probe is introduced as far as possible. This probe may be arrested at the point where the duct curves over the masseter muscle even though the fistula is some distance posterior. After the cheek is opened, the probe can be manipulated under direct vision for a distance further along the duct. A second probe is now introduced into the fistula and worked anteriorly through the duct as far as possible.



FIG. 9.—Case 3: Oral injection of left parotid duct with lipiodol visualized only a small narrowed portion of the distal segment Some lipiodol has diffused into the soft tissues. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

Step II: With the probes in place, an incision, using the ends of the two probes as landmarks, is made through the cheek. This brings the operator directly down upon the duct, or the remnants thereof. Considerable care should be exercised in making this dissection. In one of our cases an important branch of the 7th nerve lay directly over the duct and necessitated retraction before adequate exposure could be obtained.

Step III: After the ends of the proximal and distal probes have been located, an attempt is made to pass them through the duct to effect a junction. Sometimes, an adhesion or a single cicatricial band causes the obstruction which will give way under gentle pressure. However, where the duct is completely severed and both ends are sealed, the ends are incised; the proximal probe is withdrawn and the distal probe is passed through the remainder of the duct and out the fistulous opening.

Step IV.: The probe, with its tip at the fistula, is threaded with No. 10 tantalum wire twisted upon itself and then pulled anteriorly out through the oral opening. The wire now lies in the distal segment of the duct.

Step V: The proximal end of the twisted tantalum wire is next threaded along the duct proximal to the fistula so that it lies well beyond this opening into the origin of the duct or one of its main tributaries. By patient probing, no difficulty has been met in finding the opening of the proximal segment.

Step VI: The fistula and any portion of the twisted wire dowel which lies exposed are carefully closed with fine (No. 000) catgut and as many layers of covering are formed as possible.



FIG. 10.—Case 3: External injection of lipiodol through the fistulous opening shows the distal segment completely blocked. The proximal segment is patent. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

Step VII: The distal end of the twisted tantalum wire is then brought out through the mouth and is fastened to the skin of the cheek with a suture or adhesive tape. It is moved slightly back and forth daily; and in three or four weeks is removed by gently withdrawing it.

(C) *Postoperative Care:* Administration of 25,000 units of penicillin intramuscularly, every three hours, is started immediately; starting with the day following operation, patients are given pilocarpine hydrochloride,

10 milligrams, three times daily, at 10 A. M., 3 P.M., and 8 P.M. In addition ammonium chloride, Gm. 1, is given with each meal. Large quantities of fluids (a minimum of 3,000 cc. daily in addition to that taken with meals) are advised. The ammonium chloride is given for three days and omitted for two days. Oral hygienic measures are most important during the postoperative period.

DISCUSSION.—In recent injuries where the duct is completely severed, repair in the manner described is advised. By probing the duct from the



FIG. 11.—Case 4: A defect in the outline of the left parotid duct produced by a salivary calculus. Lipiodol was used to visualize the duct. A salivary calculus 4 mm. in diameter was later removed at operation. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

oral papilla, the proximal end of the distal segment can be located and it can be sutured to the distal end of the proximal duct which is identified by expressing saliva with gentle pressure over the gland. The wire dowel should be used as described; if not, the opening in the oral papilla should be dilated daily to encourage free flow of saliva along the normal channel. This same procedure, without the use of a dowel, will suffice in cases of surgical incision for stone (Case 4).

Tantalum was chosen as a dowel because of its benign effect on tissues. Any other wire which exhibits similar properties could be used for this purpose. Stainless steel or vitallium would, no doubt, be efficacious. One of the authors (D.B.S.) while following a technic, described by Thatcher,[10] has used stainless steel, acrillic, glass and tantalum buried in fingers and has so formed new tendon sheaths where a hopeless destruction had resulted from trauma and infection. In these cases a smooth sheath formed in three weeks. For this reason the authors advocate the retention of the tantalum dowel within the duct for at least three weeks. This is most important in



FIG. 12—Case 5: Severe chronic infection of left parotid gland following excision of duct papilla in a case of mild recurrent sialadinitis. Note the puddling of the lipiodol. (Management of Injuries to Stensen's Duct—Newman & Seabrook.)

cases where an entirely new segment of the duct must be formed.

The use of wire as a dowel follows a principle described in the literature. Any dowel, such as a ureteral catheter, which blocks the flow of saliva tends to defeat the essential purpose, which is to establish a flow of saliva along the repaired duct. The daily manipulation, back and forth, of the twisted tantalum dowel tends to prevent stasis and prevents secretions or blood clots from blocking the channel around the course of the twisted tantalum wire. The dilators and special probe designed by one of the authors (S.C.N.) tend to make the operation a comparatively simple procedure.

Furstenburg and Crosby[11] have shown that the use of pilocarpine and ammonium chloride increases the salivary flow; observation has convinced the authors that the viscidity is considerably reduced under this regimen. Thus, the thick, tenacious parotid secretions (often containing pus) soon

become thin, clear, and free-flowing. Once this has been accomplished and saliva is definitely entering the mouth along the tantalum dowel, a cure can be anticipated.

It is not unusual to have the fistula reopen for a short period of time after surgery but if the dowel is guiding saliva along the duct into the mouth, the fistula will close spontaneously. It has been the policy of the authors to seal the reopened fistula with adhesive tape. In the two cases in which this complication occurred a rapid healing was obtained in a few days.

## CASE REPORTS

**Case 1.**—Rifleman, age 20: At Aachen, Germany, November 20, 1944, the patient received shell fragment wounds of the left side of the face, the head, and the right leg. He came under our observation on February 15, 1945. All wounds were healed except for persistent salivary fistula of the left Stensen's duct in the masseter area. Lipiodol roentgenologic studies were made, and showed that both distal and proximal segments of the duct were patent throughout their entire length.

On April 9, 1945, a modified Kaufman operation was performed to establish an intra-oral fistula, and a ureteral catheter was inserted as a dowel. The external fistula was excised and the wound closed. On the fourth postoperative day, the wound broke down and fistula reëstablished itself. Because the intra-oral fistula drained little, it was felt that the catheter contributed to the obstruction of the salivary flow. The catheter was, therefore, removed, and the distal segment of the duct was dilated and probed through the normal orifice daily. The next day, saliva was seen entering the mouth through the papilla. Continued dilating and probing of the duct and the application of pressure to the external fistula closed the fistula four days later. The flow of saliva continues through its new channel. Experience derived from this case determined the course of procedure in the following cases (Cases 2 and 3).

**Case 2.**—First Lieutenant, Tank Battalion, age 26: In July, 1944, at St. Lo, France, the patient received a penetrating wound of the right side of the face which resulted in a persistent salivary fistula in the masseter area. Despite this, the patient continued on duty until June 3, 1945, when a kick by a horse fractured his left wrist. For this latter injury, he was evacuated to the Zone of Interior, and came under our observation July 30, 1945. The fistula had been discharging saliva since the original injury; the flow was markedly active after meals. Roentgenologic studies, with lipiodol injected into the oral orifice, showed only a small amount of lipiodol entering the duct, but there was considerable extravasion into the soft tissues of the face. Lipiodol injected into the fistulous opening made clear the duct system posteriorly but no lipiodol was seen anterior to the fistula. It was, therefore, determined that that portion of the duct was occluded. The operation described by the authors was performed September 19, 1945. The postoperative course was uneventful except for the formation of a marble-sized cystic swelling over the wound. This disappeared after several aspirations. The dowel was removed after three weeks.

**Case 3.**—Infantry Rifleman, age 22: On April 22, 1945, on Okinawa, the patient was hit in the left side of the face by a mortar shell fragment; a left parotid fistula over the masseter area resulted. He came under our observation on July 9, 1945. Lipiodol studies revealed obliteration of the distal part of the duct except for a narrowed terminal portion with multiple sinuses which lead into the soft tissues. The patient was operated upon on September 19, 1945. Convalescence was uneventful except for a temporary reopening of the fistula. This closed spontaneously in four days. The dowel was removed in three weeks.

**Case 4.**—Infantryman, age 22: This patient was first seen on January 15, 1944. His history revealed recurrent attacks of swelling of the left parotid gland. The present attack was of three weeks' duration. Roentgenologic studies showed a stone in the masseter area of Stensen's duct. This was removed by operation, on February 1, 1944. The duct was sutured with fine silk and the tissue was closed in layers. No dowel was used, but other features of the recommended postoperative treatment were carried out. Convalescence was uneventful.

**Case 5.**—Air Corps Mechanic, age 20: This patient gave a history of recurrent infection of the left parotid gland. During the course of the most recent attack, the attending surgeon had removed the papilla in order to enhance drainage. Severe and continued infection of the gland followed. Such was the condition when the patient came under our observation. Despite all forms of local and systemic therapy, the infection continued unabated. Symptoms could only be relieved by complete destruction of the gland, which was accomplished by deep roentgenotherapy. It is the author's opinion that removal of the papilla with the resultant exposure of the duct to the continuous contamination from the oral cavity so aggravated the condition that the entire gland had to be sacrificed.

## CONCLUSIONS

1. Salivary fistulae of the parotid gland and duct respond to appropriate treatment regardless of chronicity.

2. An operation and a system of preoperative and postoperative care are described.

3. The importance of preserving the duct papilla is stressed.

The authors gratefully acknowledge the splendid coöperation of Miss Susan H. Wilkes, of the Vanderbilt University School of Medicine, in the preparation of the illustrations in the limited time allotted.

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# MASTECTOMY FOR GYNECOMASTIA THROUGH A SEMICIRCULAR INTRA-AREOLAR INCISION*

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GYNECOMASTIA, or abnormal enlargement of the male breast, is a condition in which the appearance of the breast simulates that of the female. The condition may be unilateral or bilateral. An operation for its correction is herewith presented which has been employed on 32 breasts in a series of 17 cases. This paper does not deal with the surgical treatment of the malignant type of male breast hypertrophy.

Temporary swelling of the male breast may occur at puberty or during adolescence and this may recede spontaneously without requiring treatment. There are cases of gynecomastia occurring usually in adults with associated hyperplasia or tumors of the adrenal cortex. Removal of the tumors causes reduction of the size of the breasts.[1-4]

There are three classes of benign hypertrophy of a permanent nature which necessitate treatment: (1) Periductal connective tissue hypertrophy without adipose tissue change; (2) increase in the amount of both of these elements; and (3) adipose tissue hypertrophy alone.

In the first group the mammary gland is hypertrophied to form a firm discrete nodule beneath the areola and adjacent skin. A well-defined white fibrous tissue is found on gross examination, while microscopic examination reveals elongated ducts and ductules surrounded by a mass of connective tissue and complete absence of adipose tissue within the nodule. The intraductal epithelium may be hypertrophied so as to form projections into the lumens of the ducts, but with no evidence of malignant changes. No true acini are found as in the female mammary gland, although terminal ductules may somewhat resemble those acini. The condition is either unilateral or more commonly bilateral, and it usually appears at puberty.[5-7] The patients in this group have the normal male type of body and genitalia and the firm gland is readily palpable as a nodule.

In the second, or intermediary group, the connective tissue elements may be predominant or they may exist only in small amount in the region beneath the areola with the remainder of excess tissue composed of adipose tissue. The body may be of the feminine type, eunuchoid, or of the normal male type. The genitalia may be normal or underdeveloped, with atrophy of the testicles from various causes. One or both breasts may be involved and ordinarily a subareolar nodule can be palpated. Onset is commonly at puberty but may be postponed until later in life.

* Presented before the combined meeting of The New York Surgical Society and The Philadelphia Academy of Surgery, February 14, 1945.

In the third group the increase in size of the breast is due entirely to excessive adipose tissue with no mammary gland hypertrophy. The body is of the Froehlich type and the genitalia are underdeveloped until late in

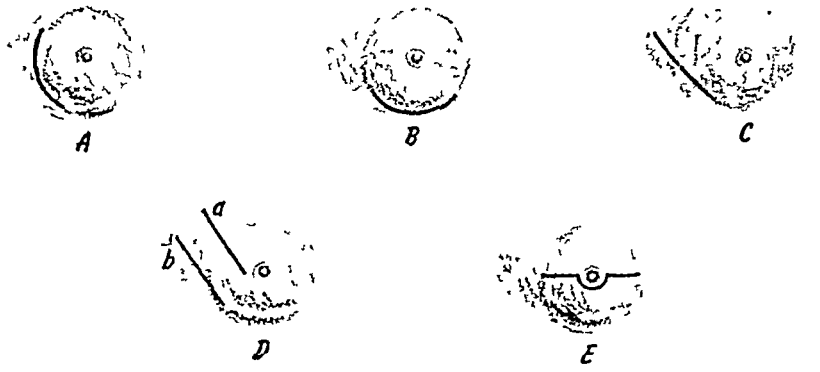



FIG 1.—Schematic diagrams of simple incisions in extra-areolar skin for male mastectomy as reported in the literature.

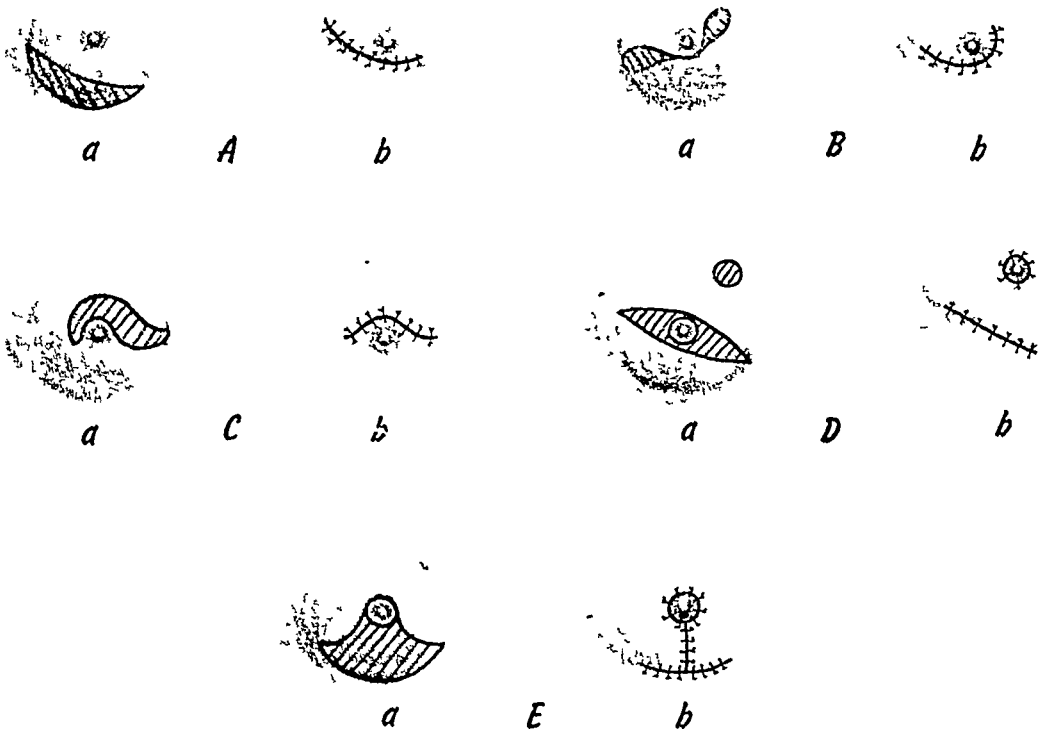



FIG 2.—Schematic drawings of more complicated operative procedures advocated by various surgeons.

puberty, when they generally attain normal size. The condition is bilateral and appears in the first decade of life, but usually does not cause the patient concern until the age of puberty. No nodule is palpable beneath the areola.

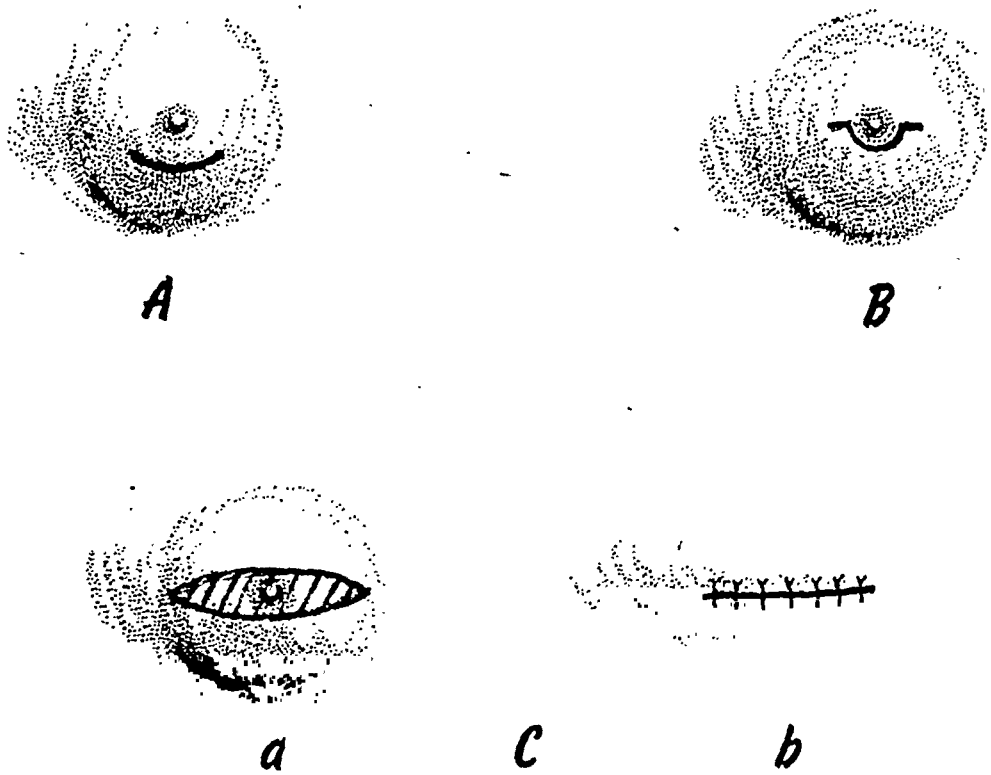



FIG. 3.—Unreported procedures at one time in vogue at the Presbyterian Hospital.

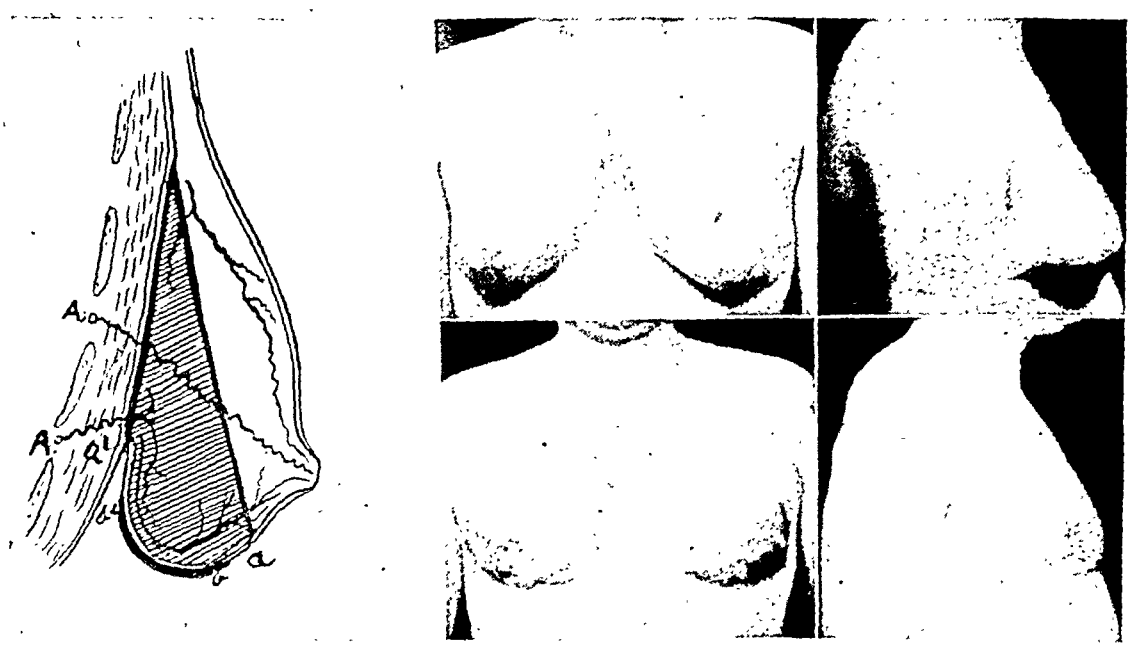


FIG. 4.—Diagram of Maliniac's procedure and illustrations of cases. (From J. Clin. Endocrinol., 3: 364–366, 1943[16])

Methods of treatment advocated for gynecomastia have been radiotherapy, endocrine therapy, and operation. It is now generally conceded that radiotherapy offers no chance of improvement of the condition.[8] Dr. William Schonfeld reported from our Endocrine Clinic that in his experience all types of treatment with various hormones failed to reduce the breast in a single case, even when male sex hormones were injected directly into the breast.[5] It is possible that in the reports of cure by endocrine therapy some of the cases of breast hypertrophy were of the temporary type and would have receded spontaneously even without treatment.[9-11]

Surgical removal of the excess breast tissue offers the best method for the correction of gynecomastia. The indications for operation are: To remove the threat of subsequent malignant changes in the enlarged breast; to relieve pain; and to prevent the psychic trauma caused by the feminine appearance of the breast.



FIG. 5.—Diagram of Vogt's procedure and illustrations of case. (From Chirurg., 10: 322–324, 1941[17])

Carcinoma of the male breast developing late in life occurs extremely rarely, and the number of cases seen is small in relation to the large number of gynecomastia cases. It is readily distinguished from the benign type of mammary hypertrophy.

The complaint of pain as a cause for seeking relief has been recorded,[12] especially by doctors in the Armed Forces — however, one suspects that frequently the true cause for complaint was the unwelcome shape of the breast rather than actual pain.

The psychic trauma caused by "the reproach of effeminacy" is the main reason for operative interference in gynecomastia of the benign type. In modern life when exposure of the body is so frequent, and this is particularly the case in military life,[13, 14] the gynecomastia patient is subjected to jibes and teasing from his fellows. The repeated ridicule may bring about changes in the individual's behavior patterns. He hesitates to undress before others in the gymnasium or on the beach, and he refrains from going in swimming. He may even shrink from exposing himself in a thin undershirt. Thus, a complex is started which may lead to severe psychotic disturbances.

That this deformity causes acute psychic trauma has been recognized for centuries. Paulus Aegineta[15] (625–690 A.D.) described the condition of gynecomastia, which he thought was due to "the formation of fat." In order to improve the mammary appearance he advocated removal of the excess tissue through a single submammary lunar incision or, in marked cases, through two lunar incisions coming together at the ends and with excision of the subtended skin. Ever since the seventh century this procedure has been used extensively, and other types of incision for removal of the excess of tissue have been devised (Figs. 1–7).[16-27] In all the operative procedures we have found reported, the incisions have been made through the moderately thick skin outside of the areola. The skin in this area does not lend itself to ideal healing as scars resulting from incisions in this region, even after meticulous closure, are usually broad and conspicuous. Surgeons have even advocated removal of the entire areola together with the excess of breast tissue to overcome gynecomastia—when operation was admittedly performed to improve the mammary appearance.[1]



FIG. 6-A

FIG. 6-A.—Cases of Campos operated by two procedures.
(From Arq. de Cir. Clin. e Exper., 6: 703–705, 1942[18])

There is no indication that any surgeon has recognized that the scars resulting from these operations may cause nearly as much embarrassment as the original condition, especially so when the scars are bilateral and symmetrical and explanation of their presence is made more difficult. Nor has an operation been devised that prevents the formation of visible scars that give evidence of operative interference, an ideal which should be sought in order to secure complete success from the psychologic standpoint.

With this object in view, an operation with a semicircular intra-areolar incision was devised by the author, and was first performed in 1934. The results were so satisfactory that the method has been employed in all 15 subsequent cases treated on the Division of Plastic Surgery. In 1944, Comdr. George V. Webster, U.S.N.R., formerly a resident on this Service,

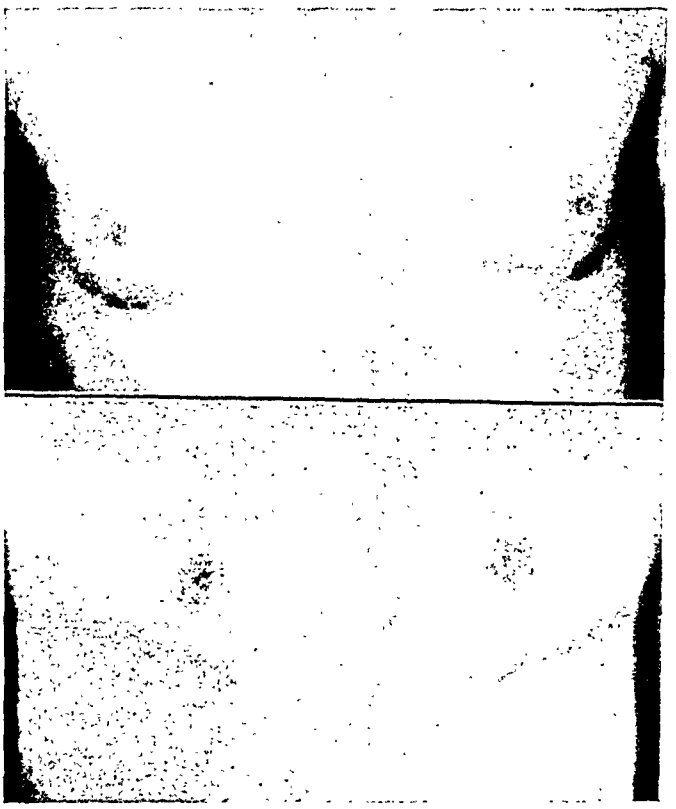


FIG. 6-B.—Cases of Campos operated by two procedures.
(From Arq. de Cir. Clin. e Exper., 6: 703–705, 1942[18])

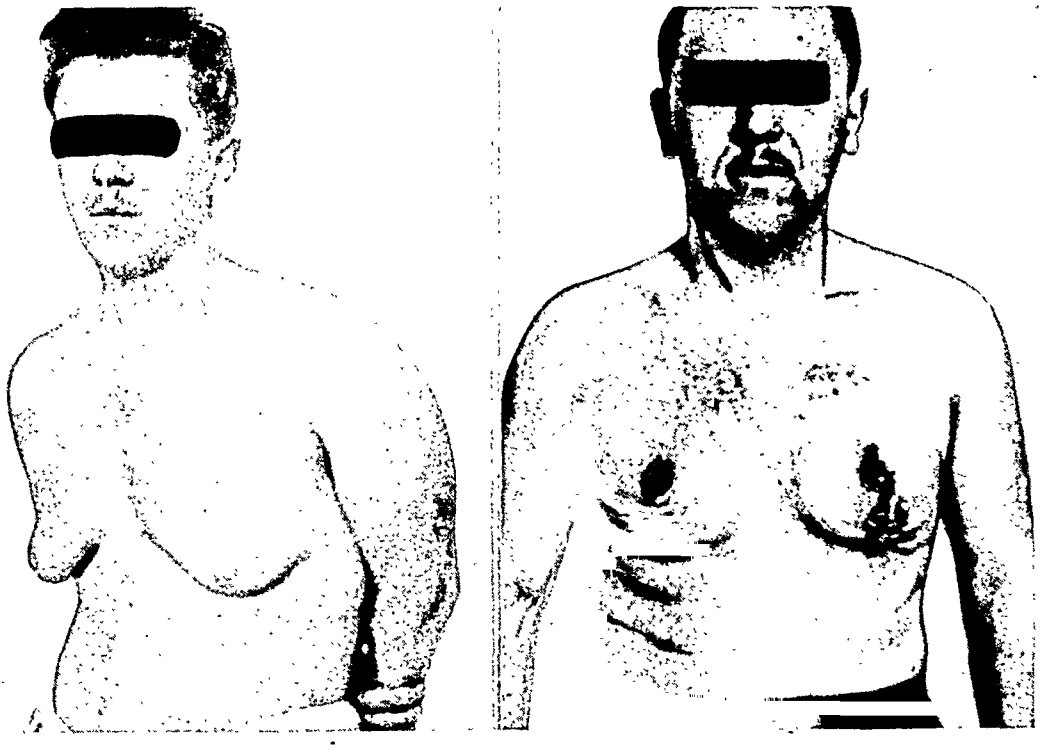


FIG. 7.—Case operated by Adler's method similar to mammaplasty for hypertrophy of the female mammary gland.
(From Zentralbl. f. Chir., 64: 889–893, 1937[19])

reported the procedure as performed at this clinic and later by him in the Navy.[28]

### OPERATIVE PROCEDURE

The operation is performed under general anesthesia. If the condition is bilateral two operative teams are used simultaneously to reduce the length of the operative time. Care must be taken that the procedures used by each operator are similar and that the tissue left remaining on each side is of the same amount so as to obtain symmetrical surface contours.

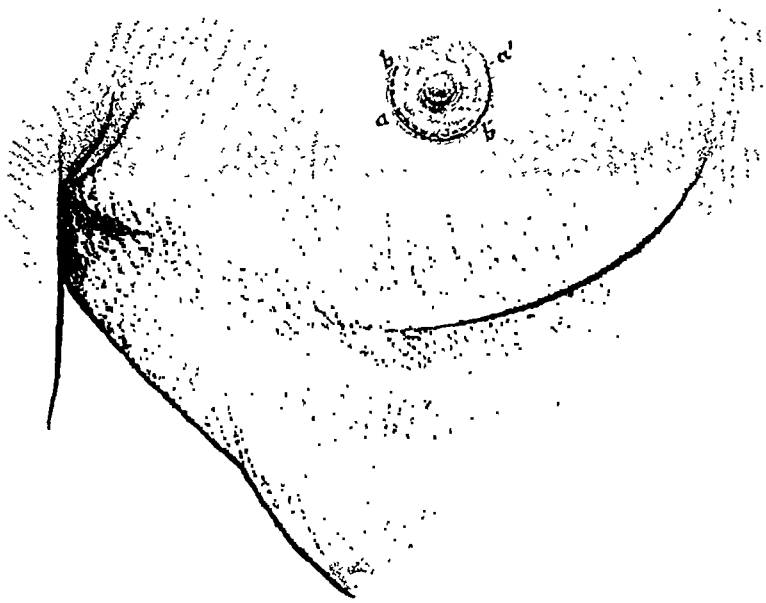



FIG. 8.—The author's operation. Semicircular intra-areolar incision—a-a′ in caudad half of areola; b-b′ in laterocaudad half of areola, to facilitate removal of tissue toward the axilla.

The areola is distended by pressure exerted downwards about the breast by the encircling hands of the assistant. A semicircular incision is made just within the margin of the pigmented area of the areola. It may either extend over the lower, or caudad, half of the areola, or be placed more laterally (Fig. 8) when much tissue towards the axilla has to be excised. Incisions in the areola leave fine inconspicuous scars. If they are made at the outer edge of the areola in the thicker derma the scars will be more evident. Dissection beneath the areola with division of the ducts may be made early to facilitate operation (Fig. 9). Excision is aided by traction upwards with Kocher clamps on the divided ductal stump (Fig. 10) or on the mass of tissue that has been freed. The introduction of a palpating finger and incision against this with curved scissors is helpful. Bleeding points should be clamped and tied early, to reduce the amount of bleeding and improve vision. Enough adipose tissue must be left to be drawn together eventually beneath the nipple if such a layer does not cover the pectoral fascia; incisions

may be made in the adipose tissue between the skin and the remaining cut-surface of adipose tissue for later advancement of a fat layer towards the center.

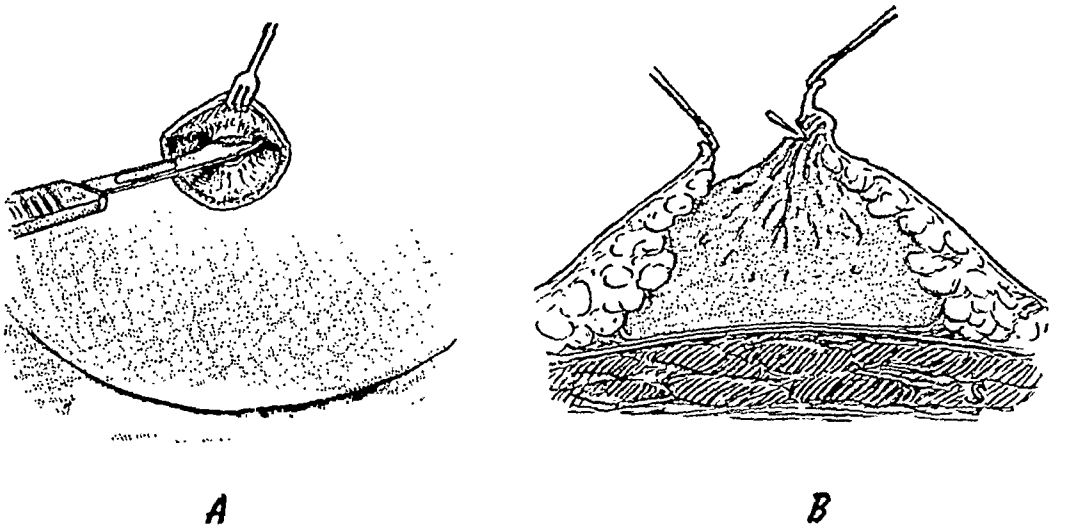



FIG. 9.—Retraction of areolar flap and division of breast ducts.

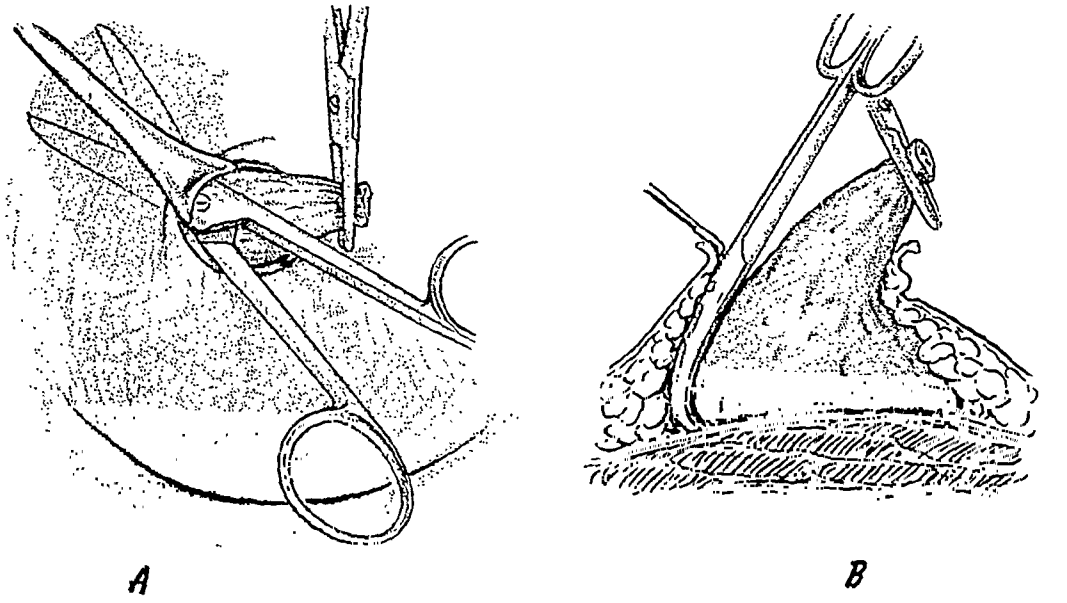



FIG. 10.—Excision of breast tissue with traction outwards aided by a Kocher clamp.

If the areola is small in comparison with the amount of tissue to be removed through the incision, the tissue may be halved or quartered and individual portions can be separately removed (Fig 11).

If the periductal connective tissue is well developed, as in Group I, dissection will be comparatively easy. If there is no fibrous tissue plane to

follow and adipose tissue has to be excised, the operator must use his judgment in cutting evenly at a satisfactory depth through the subcutaneous fat so as to remove a cone-shaped mass of tissue tapering away to nothing at the periphery (Fig. 12). Sufficient fat must be left over the pectoral fascia to obtain a smooth, even surface when the remaining tissues are replaced. Reduction of the adipose tissue should be sufficient to overcome the similarity to the female breast, but the amount remaining should not be disproportionate to the amount of subcutaneous fat found elsewhere on the body. In the intermediate type of case a fibrous tissue plane can be followed where this exists, but in proceeding laterally incision must be made without this aid.

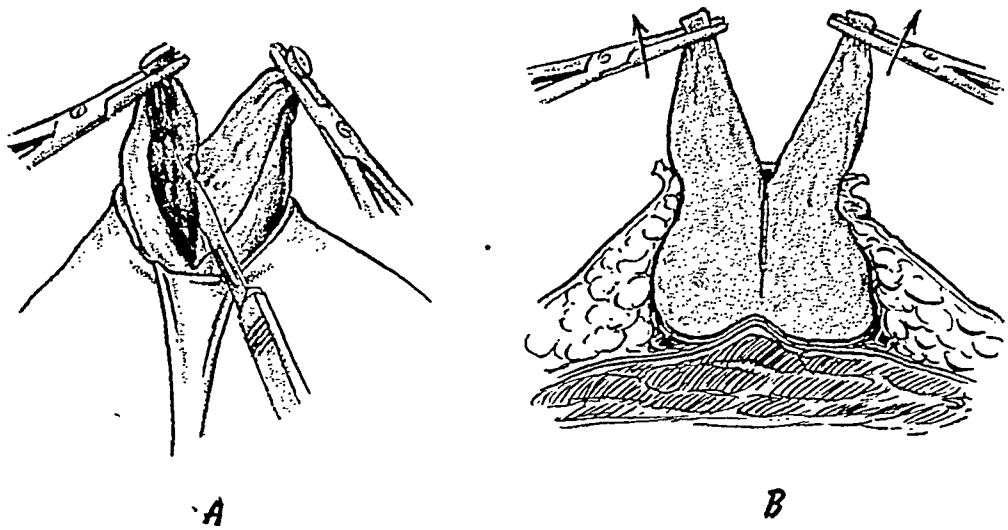



FIG. 11.—Division of breast tissue into two masses to be removed separately.

In closure the use of unabsorbable sutures, such as silk, is recommended, in order to prevent subsequent separation of the tissues which have been brought together. To close the wound satisfactorily is one of the most difficult phases of the operation. By a "trial and error" method the subcutaneous fat is sutured together (Fig. 13) so as to form a uniformly thick layer over the pectoral fascia and in such a way as not to leave the areola distorted after closure. The nipple must not be allowed to adhere directly to to the pectoral fascia, nor must there be a concavity in the mammary region. It is advisable to err slightly on the side of excessive removal of adipose tissue, because what may appear to be sufficient on the operating table when the patient is supine subsequently may appear insufficient when erect. After bringing the subcutaneous fat together (Fig. 14) the wound in the areola is closed in two layers (Fig. 15), so as to approximate smoothly both the lower derma and the skin edges.

If the skin at the edge of the wound has been devitalized through pressure of retractors careful smooth débridement of this tissue must be made. Hemostasis should be adequate and closure without drainage is desirable. A

voluminous dressing with moderately firm pressure from an Ace bandage should be applied. Too much pressure may cause necrosis of the nipple. Postoperative coughing should be encouraged to prevent the possibility of atelectasis.

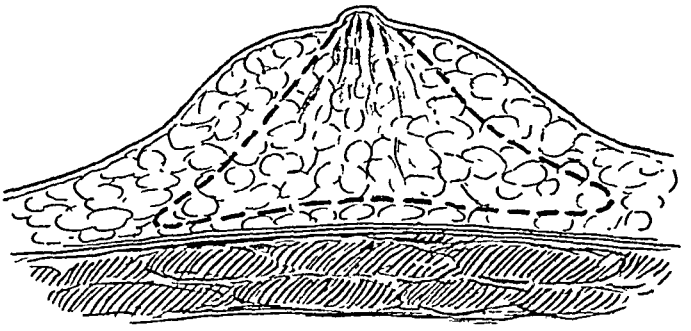


FIG. 12.—Outline of incision in adipose tissue when this is largely responsible for enlargement of the breast.

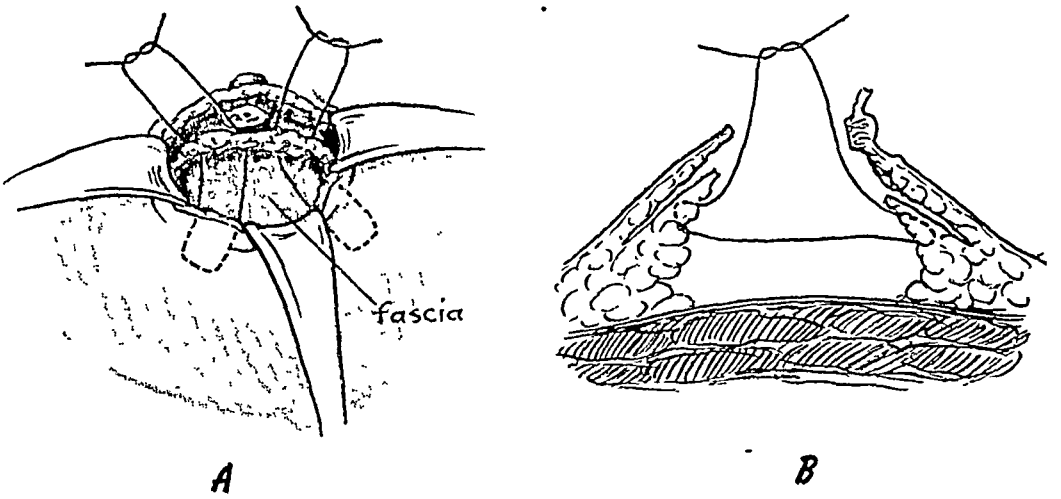



FIG. 13.—Suture of adipose tissue to bring tissue beneath the areola after having made relaxing incisions in subcutaneous tissue.

## ANALYSIS OF CASES

In this series of 17 cases there was unilateral hypertrophy on the right side in one patient, Case 12, (Figs. 24 and 25), and on the left in another; the condition was bilateral in the remaining 15 patients, two of whom were colored; thus, a total of 32 breasts were operated upon.

The onset of the condition was said to have occurred from nine years of age to 19, with the onset in ten of the 16 cases during the 12th and 13th years. Those patients exhibiting Froehlich's syndrome showed enlargement of the breasts at an early age, as was to have been expected. Operation was performed in all 17 cases six months to 20 years after the onset of the condition, the average duration of the condition before operation being seven years.

Specimens from two patients, Cases 1 and 15, (Figs. 16 and 17) showed only well-encapsulated periductal connective tissue thickening with no adipose tissue hypertrophy. Both of these patients had normal male contours of body with normal genitalia.

The specimen in another patient, Case 4, showed no adipose tissue within the well-encapsulated mass of breast tissue, but there was a slight rim of

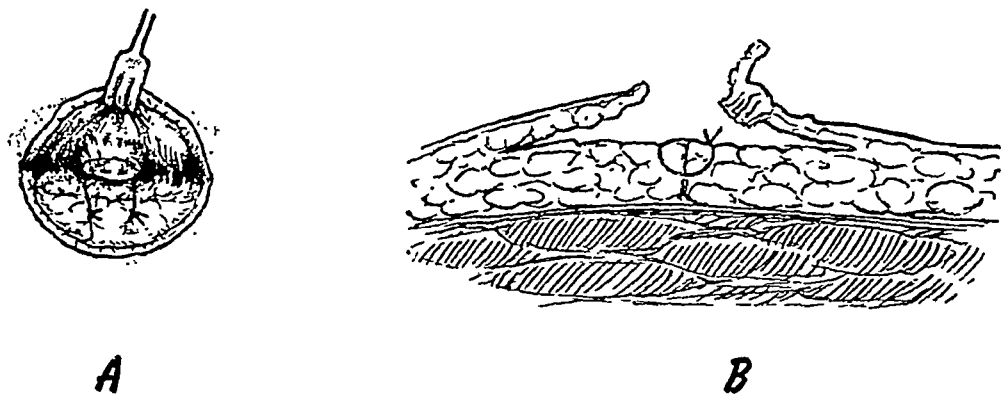



FIG. 14.—Adipose tissue brought together with sutures so as to cover the pectoral fascia.

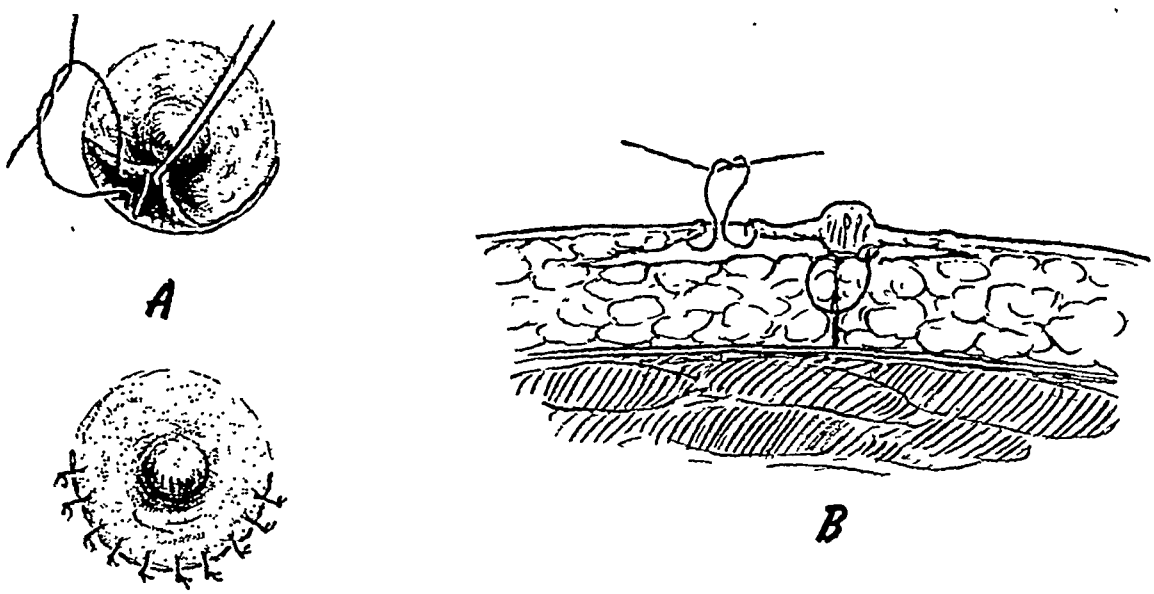



FIG. 15.—Closure of areolar wound in two layers.

adipose tissue at the periphery of the gland. This patient at the age of 12 had had a bilateral herniorrhaphy and operation for left undescended testicle performed at another hospital. Both testicles had atrophied and were barely palpated. The enlargement of the breast began at the age of 19. Subsequently, very extensive hormonal treatment was instituted which brought out secondary sexual characteristics, with the appearance of a beard and hair on the body, particularly after the use of oretone. However, this

treatment failed to reduce the size of the breasts. While under very intensive hormonal treatment there was thought to be some decrease in the size of the breasts, but this was explained by the decrease in the subcutaneous fat everywhere. His original eunuchoid appearance changed under hormonal therapy to normal male type. He was 27 years old when operated upon, having had the condition for eight years.

FIG. 16

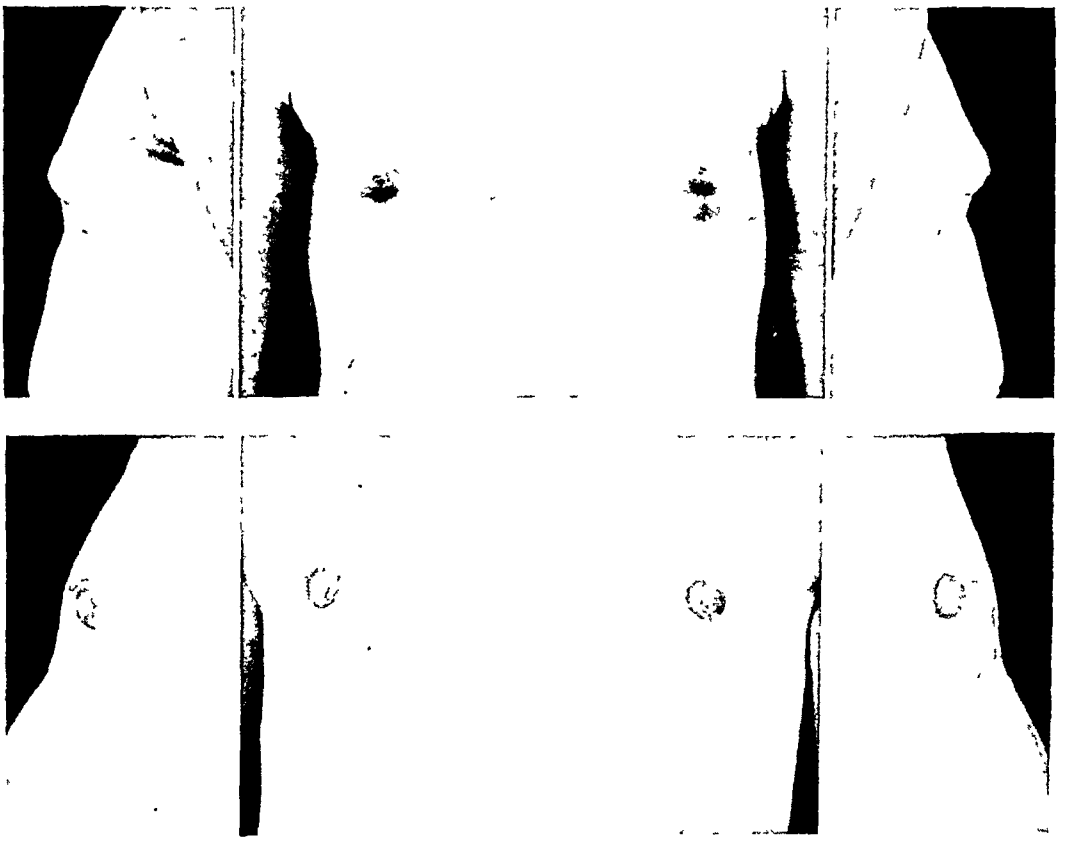


FIG. 17

FIG. 16.—Case 1: Condition before operation in a 15-year-old boy with normal male type of body and genitalia. Onset at age of 13. Patient teased a great deal and very sensitive.

FIG. 17.—Case 1 (cont.): Condition seven months after operation showing normal appearance of male pectoral region, areolae, and absence of noticeable scars. Hypertrophy found due entirely to enlarged periductal connective tissue with no adipose tissue present. Patient "not kidded any more."

Three patients, Cases 7, 17 and 10, (Figs. 22 and 23), showed absolutely no mammary tissue in the specimens, the enlargement being entirely due to adipose tissue with moderate fibrous tissue strands. Two of these patients were definitely of the Froehlich type (Cases 7 and 17) with slightly underdeveloped genitala. One patient, Case 10, was mildly obese, very hairy, and had normal genitalia.

The remaining cases were of the intermediary group with both breast tissue and adipose tissue combined in varying proportions.

Ten cases received hormonal therapy in the following amounts: Case 3+, Case 4 ++++, Case 5 ++++, Case 8 +, Case 9 ++++, Case 10 ++++, Case 11 +? (elsewhere), Case 13 + (elsewhere, for undescended

FIG. 18

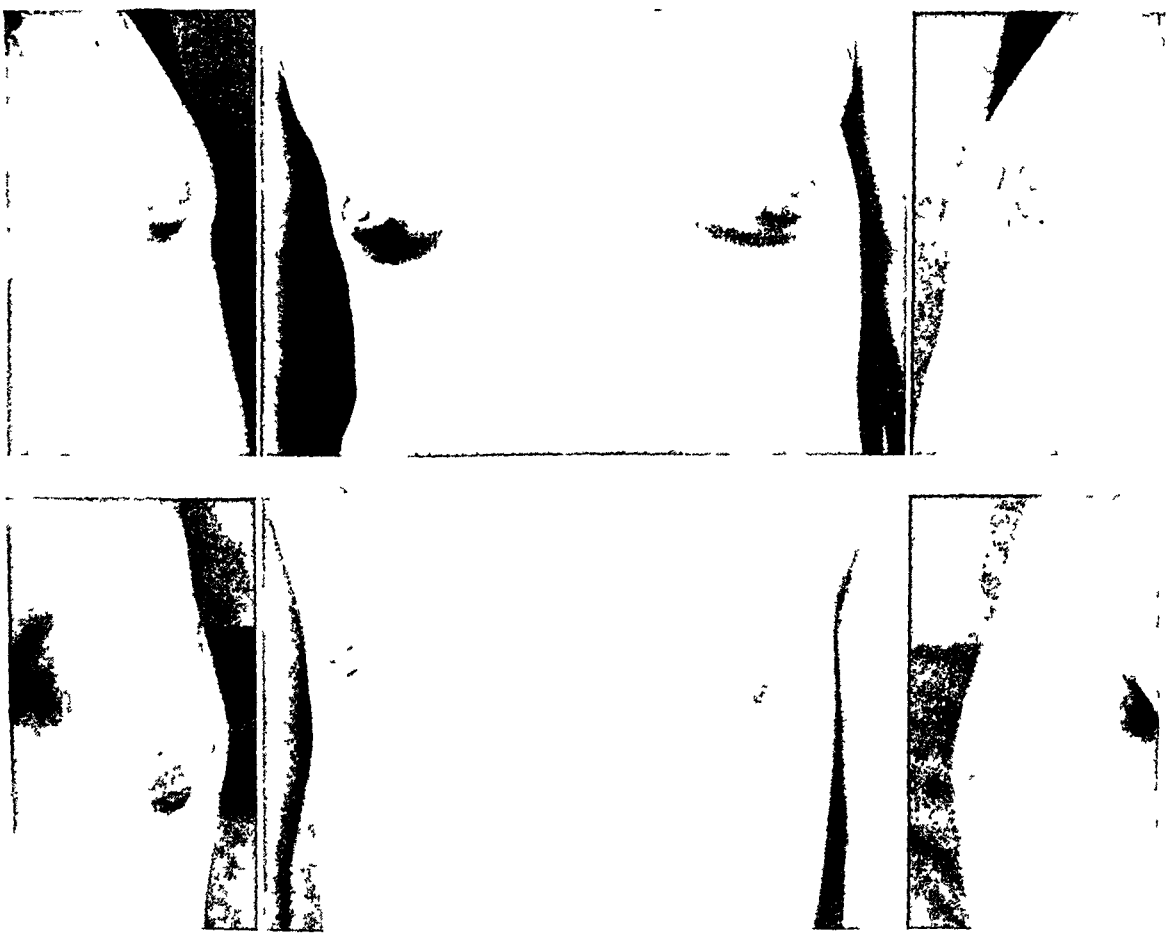


FIG. 19

FIG. 18.—Case 9: Preoperative condition in a 14-year-old colored boy with obese feminine type of body, female distribution of pubic hair, and normal male genitalia. Condition began at age of 12. Extensive treatment with testosterone and oretone injected into left breast resulted in no appreciable change in the size of breasts. Patient embarrassed to undress before others.

FIG. 19.—Case 9 (cont.): Condition 16 months later, and five weeks after operation. Breast tissue composed of ducts and ductules, connective tissue and fat, showing fat necrosis with cavitation from oretone pellets. Patient very pleased with result of operation.

testicles), and Case 14 ++++. The remaining patients were not given any endocrine therapy.

In no case was any complaint made of pain in the breasts although one patient recalled having had pain. All 17 patients gave a history of embarrassment because of the condition prior to operation. This was not admitted in one case, Case 6, but the reason he gave for seeking treatment was because "the swimming season was approaching."

One patient, Case 7, (Figs. 22 and 23) repeatedly went home crying because of being teased. In this patient a collection of serosanguineous fluid developed postoperatively in one breast, and this fluid was aspirated on one occasion. This aspiration brought the breast down to normal limits but subsequent thickening persisted. Probably more tissue should have been excised, and operation on this breast will have to be repeated. Nine months

FIG. 20

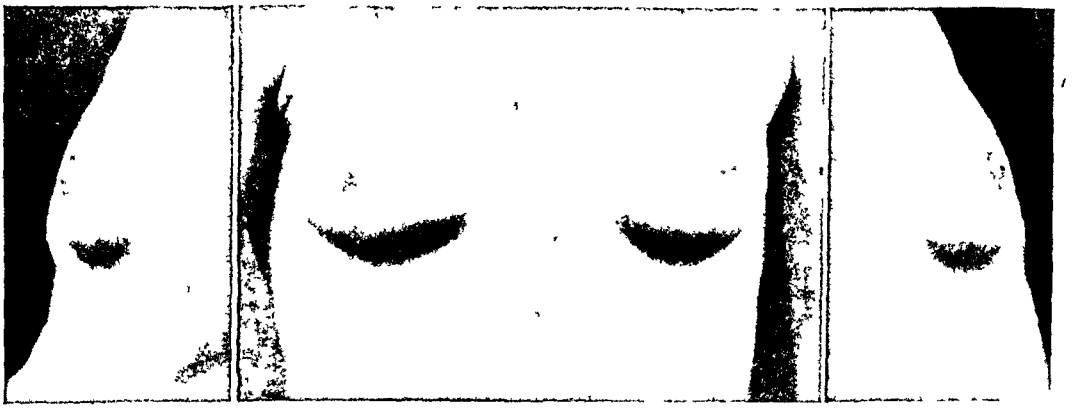




FIG. 21

FIG. 20.—Case 8: Condition before operation in 17-year-old boy with well-developed male type of body. Condition appeared at age of 13. Second degree hypospadias, with good operative correction Testicles normal size. Two oretone pellets inserted into left breast (note scar) without improvement Acute embarrassment when undressing in gymnasium.

FIG. 21.—Case 8 (cont.): Condition one month after operation. Specimens showed both periductal connective tissue and adipose tissue hypertrophy. Serosanguineous fluid was aspirated from both breasts on 5th and 7th postoperative days. After operation and changing schools patient had no hesitancy to undress in gymnasium.

after operation this patient was still unwilling to undress before others because of the enlarged left breast.

One patient (Case 14) with a Froehlich's syndrome and an atrophied right testicle and undescended left testicle, in whom the enlargement of the breasts was found to be due almost entirely to adipose tissue, still has some-

what prominent breasts, particularly on the right side. This is noticed especially when standing. This patient is still unwilling to expose his breasts when undressed or in swimming. It is more difficult to know exactly how much adipose tissue to remove in the cases in which enlargement is due to an increase in this tissue than in the cases in which the mammary tissue itself is the predominant cause of the enlargement.

FIG. 22



FIG. 23

FIG. 22.—Case 7: Preoperative condition in 15-year-old boy of Froelich type but with normal male genitalia. Onset said to have been at ten years of age. Futile extensive testosterone therapy with repeated injections of oretone into left breast. Breasts large, areolae small. Patient teased unmercifully and frequently "came home crying."

FIG. 23.—Case 7 (cont.): Condition five months after operation. Specimens showed only adipose tissue hypertrophy with no breast tissue or ducts observed. Twenty cubic centimeters of serosanguineous fluid aspirated from left breast on 9th postoperative day. Probably insufficient tissue removed from left breast. Patient dissatisfied with postoperative condition of left breast and was unwilling to undress before others.

Another patient, Case 8, (Figs. 20 and 21) postoperatively developed a collection of serosanguineous fluid in both breasts. Thirty-five cubic centimeters were aspirated from each breast five days after operation, and 20 cc. from the right breast and 10 cc. from the left breast one week after operation. This patient had an excellent final result and his previous embarrassment when undressing for gymnasium classes was completely eliminated.

Case 11 represents an unsatisfactory result. The operation was performed by two residents on the author's service. This patient was a case of true eunuchism, with no testicular remnant recognizable. His breasts had started enlarging at the age of 13, and his body weight increased until he weighed 260 pounds six months before he was seen in the Plastic Surgery Clinic. By dieting he lost 60 pounds. Both breasts were large, the left

FIG. 24

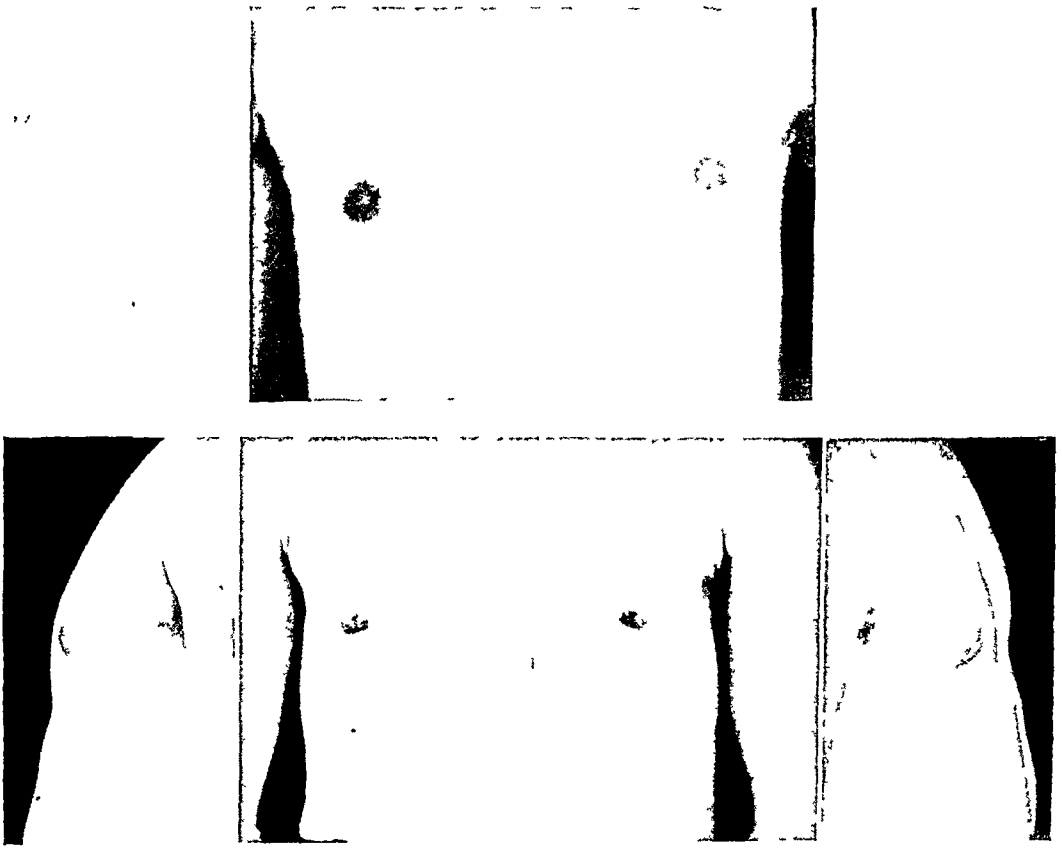


FIG. 25

FIG. 24.—Case 12: Unilateral right gynecomastia in 27-year-old man with normal male type of body and genitalia. Areolae and nipples dark and minutely papillomatous. Condition began at age of 16. No preoperative hormonal treatment. No marked complex before operation but "has feeling of guilt."

FIG. 25.—Case 12 (cont.): Postoperative condition seven months after operation. Specimen showed hypertrophy of numerous ducts, connective and adipose tissue. Patient wears trunks and goes swimming without qualms.

being pendulous and shaped like that of an adult female. When the specimen was examined microscopically the hypertrophy was found to consist almost entirely of fat with some connective tissue present. No ducts were observed. The specimen from the left breast weighed 450 gm., and measured 14 x 13 x 4 cm., while that from the right breast weighed 430 gm., and measured 15 x 10 x 4 cm. These represented the largest amounts of tissue removed from any patient in this series. Drainage was instituted at operation

through the right areolar incision, this being the only patient in the series who was drained. On the 9th and 12th postoperative days, respectively, 98 cc. and 35 cc. of serosanguineous fluid was aspirated from the left breast, and there was early serosanguineous discharge from the drainage wound in the right breast. There was necrosis of approximately one-third of the entire right areola and one-half of the left areola, apparently due to redundancy of the tissue with folding-in of the areola and the application of a very tight pressure dressing. The wounds did not heal until 82 days after operation. The excessive volume of the breasts was reduced but the nipples were definitely deformed. The patient did not return to the clinic after the wounds healed, as he was apparently drafted into the Army. The results in this case were far from ideal because of the deformity of the nipples. It was, however, more satisfactory than some cases reported in the literature.

Another patient, Case 16, recently operated upon, had very superficial necrosis of both areolar flaps and 15 cc. or less of serosanguineous fluid was aspirated from the left breast on three occasions. It was thought that the cause of the superficial necrosis was the application of an excessively tight bandage. The final appearance was excellent.

There was no infection in any of the breasts operated upon in the series, with the exception of the surface suppuration of the necrotic areolae in Case 11.

Dr. Thomas W. Stevenson operated upon the opposite side from the author in Cases 1 and 2. He was the attending surgeon in charge of Cases 3, 5, and 6 and took part in the operations in Cases 3 and 6.

## SUMMARY

1. The indications for corrective therapy for gynecomastia are discussed with emphasis on the importance of overcoming the psychic trauma caused by the female appearance of the male breast.
2. Of the various therapeutic measures that have been advocated, operation offers the most satisfactory result.
3. Extra-areolar incisions for removal of breast tissue leave scar deformities that indicate operative interference; therefore, such procedures fail to attain the best psychologic results.
4. A mastectomy operation through a semicircular intra-areolar incision is here presented by which the excess breast tissue is removed leaving a practically invisible scar.
5. Over a period of 12 years, 17 patients requiring 32 mastectomies have been operated upon by this method, with almost uniformly excellent results; and the preoperative complexes have been overcome in nearly all cases.

## CONCLUSIONS

Mastectomy through a semicircular intra-areolar incision for the correction of gynecomastia is a procedure which offers many advantages over

operation with other types of incision. The results of this procedure on 32 breasts were almost uniformly excellent, the insufficient reduction in the size of the breasts in Cases 7 and 14 and the deformities of the nipples from necrosis in Case 11 being the only exceptions. The final appearance in all cases may be favorably compared with the results obtained by other procedures. The absence of noticeable scars such as occur with extra-areolar incisions, together with the reduction of the breasts to normal size and contour, removes the cause of the patient's psychic disturbance. Since the normal appearance of the male pectoral region is achieved by this operation with almost no evidence of operative interference, the patient can indulge in normal activities and expose his chest without fear of ridicule or need of explanation.

The operation requires careful technic and meticulous hemostasis, together with considerable skill, judgment, and patience on the part of the operator to remove a proper amount of tissue along optimum planes and to close the wound satisfactorily in the depths as well as on the surface. It is felt, however, that this type of operation, which leaves inconspicuous scars, should be employed when mastectomy for gynecomastia is to be performed.*

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*This operation has been performed once upon a 14-year-old colored patient with true hermaphroditism.[20] The breasts were similar in size and shape to those of a 16-year-old girl but the patient desired to live as a man. A slight excess of tissue was left on one side.

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# SUBTROCHANTERIC OSTEOTOMY FOR UNUNITED FRACTURE NECK OF THE FEMUR*

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ALTHOUGH, since the advent of internal fixation after fracture of the neck of the femur by various forms of nails and screws there has been a slight increase in the percentage of patients thus injured who regained ambulation, ununited fractures of the neck of the femur still occur. Many of these have been inefficiently treated by forms of traction, either in bed or ambulatory, and a few have been victims of improper or inefficiently accomplished internal fixation by various devices.

In my presidential address before the Western Surgical Association, 1928, attention was called to the length of time required for bony union after complete reduction and treatment of fracture of the neck of the femur. Instances were cited, and illustrated, in which this healing required six months, or more, time and the criteria of healing furnished by the restoration of full trabecularization across the fracture plane shown in the roentgenologic control was first brought out. Too early weight-bearing after recent fracture of the neck of the femur, no matter how treated, is a sad mistake because although it *may* not cause secondary displacement of the fracture, the pressure against the still partly devascularized head and imperfectly healed neck (trabeculae not permanently formed) must provoke degenerative change in the cartilage and bone.

Stress on the fractured neck of the femur incidental to shearing and adduction strain may be measured in degree by the obliquity of the fracture plane to the horizontal. This was first brought out by Pauwel, and was widely recognized in the surgical world. To this obliquity must be added, as of equal importance, the rotatory force, usually turning the leg outward, which causes a separation of the fracture surfaces of the neck, which, if uncorrected, leaves a V-shaped bony defect usually on the posterior aspect of the neck. Whitman tried to overcome this in his abduction treatment.

A horizontal plane may be indicated by a line drawn through both anterosuperior spines of the ilium on the anteroposterior roentgenogram including both hips with the patient lying fully straightened out. By adding a line through the fracture plane of the neck of the femur extended to meet the horizontal line, an angle is formed of various widths depending on the obliquity of the fracture. King advised that three grades of fracture may be recognized.

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* Read before the Western Surgical Association Chicago Meeting, November 30, 1945.

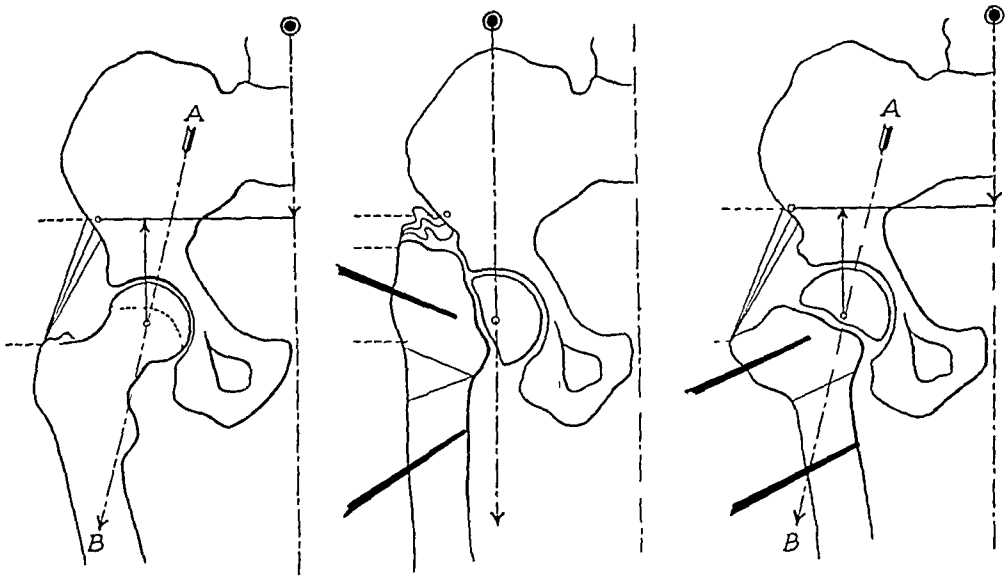



FIG. 1.—Pauwel's method of cuneiform osteotomy to correct ununited fractures neck of the femur. (From Hillebrand's article on the "Treatment of Pseudarthrosis of the Neck of the Femur." Bruns Beit. z. Klin. Chir., 157, 281, March, 1933.)

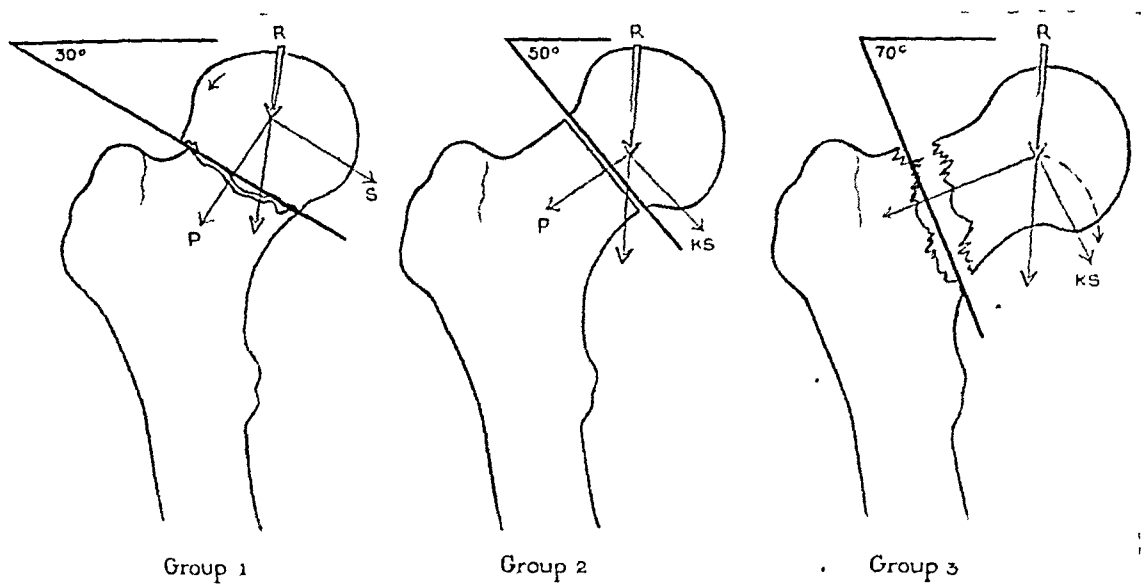



FIG. 2.—Modified from King's description of the angles formed between a horizontal and various fractures of the neck of the femur.

Group 1: Thirty degrees, or less, not requiring internal fixation when properly reduced and immobilized.

Groups 2 and 3: Requiring firm internal fixation as the angle of the fractures increased over 30 degrees with a horizontal line through the pelvis increasing the shearing stress and lessening the chance of holding reductions. (King, Thomas, Brit. J. Surg., 26, 721, April, 1939.)

Group 1.—A truly impacted or abduction fracture in a position of coxa valga, in which the angle between these two lines is from 30 to zero degrees. The fracture surfaces are nearly horizontal. Osseous union after immobilization almost invariably follows because no shearing force due to muscle action or weight-bearing exists. No operation for internal fixation is called for, according to King. In some of these instances (impacted) the patient may have walked, albeit with pain and limp, for some time before fracture was recognized, disimpaction fortunately not having occurred.



FIG. 3.—Insertion of marker about two inches below the tip of the greater trochanter of the femur after reduction of the ununited fracture of the neck, patient lying on the fracture table, leg fixed by skeletal traction through the heel. The transverse and obliquely upward osteotomy is performed with this guide for location.

Group 2.—The fracture plane in the neck forms an angle of 30°–50° with the horizontal. In this group transfixion by nail, screw or bone transplant is indicated, not only to hold the fragments together or to prevent their rotation from uncorrected eversion of the foot but to prevent the untoward action of the shearing force mentioned.

Group 3.—The fracture plane forms an angle of 50° plus up to 90°, or vertical in type. These require secure internal fixation after complete reduction to cover the points mentioned. For these extreme instances of vertical fracture, or separation, King uses both a nail in the lower third of the reduced neck to protect against rotation and lateral separation of the fracture surfaces and also a full-thickness fibular graft above the nail to fit tightly into the head of the femur to prevent tilting of the head and resulting coxa vara. This fibular graft may also supply an osteogenetic stimulus, hopefully leading to prompt bony union.

In old ununited fractures the fracture plane has become almost vertical due to absorption of the lower part of the neck and rise of the trochanters — it may be classified with Group 3. To assist these unfortunates, many of whom are elderly and yet not completely discarded individuals, who have agility and mental powers which may still make them worth while, osteotomy just below the neck of the femur has offered unbelievable hope of restoration of ambulation, with some restrictions.

Subtrochanteric osteotomy aims to alleviate pain in the hip, to restore bony union, of a sort, and consequently assist, or render possible, weight-bearing and ambulation, with restoration of the individual's freedom of action and usefulness. The operation itself is done quickly, it involves little shock and brief anesthesia, its results are often beyond expectation. It is usually reserved for patients 60 or more years old.

The cause of the nonunion excluding septic infection (usually from an operation) or aseptic necrosis of the head from interfered with blood supply, usually beyond the surgeon's control, can not fully be discussed here. Subtrochanteric osteotomy may be used to treat older people, or those whose fracture has been neglected or poorly treated for a longer period of time

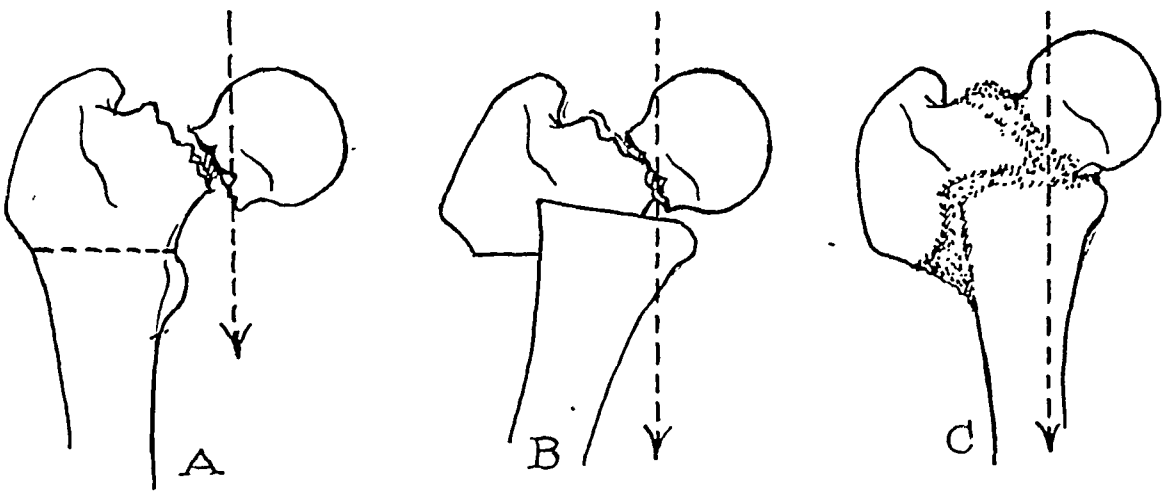



FIG. 4.—Diagrammatic representation of the subtrochanteric osteotomy:
(A) The line of osteotomy is too straight and should be directed diagonally upward.
(B) The shaft fragment is pushed in and
(C) A healing process has occurred not only to the trochanter but to the neck with the weight-bearing line now passing through the head of the femur directly into the shaft as indicated. (From the Author's text on Fractures and Dislocations, Lea and Febiger, Philadelphia.)

than is usually accepted as the clinical limit for more complicated surgical methods, such as bone grafts or reconstruction operations. I wish to review briefly the mechanics, pathology, technic, after-treatment and results of subtrochanteric osteotomy.

Ununited fracture may result from primary lack of diagnosis; incomplete or no roentgenogram from the extreme obliquity of the fracture of the neck which inhabits firm and holding apposition of fragments; improper or incomplete reduction; too short a period or too weak traction, if used, and improper and inefficient internal fixation, if attempted. The last named method is still further jeopardized by a belief that the patient may walk on the nailed, or screwed, neck of the femur in a few days. In the face of an

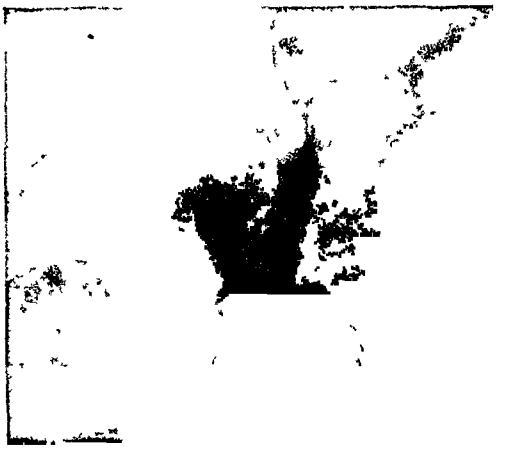


FIG. 5.—Ununited fracture neck of the femur of nine months standing.

oblique angle of more than 30° was described, he can not safely and universally do so. He usually requires a bony union before ambulation with weight-bearing should be attempted—an average of six months' time. If he bears weight before that period of time, the natural obliquity of the angle of the neck of the femur, enhanced by the additional obliquity of the fracture plane, is bound to result in coxa vara restricted and painful motion; leg shortening; foot eversion; and often hip joint pain and ultimately breaking down of the head with proliferative arthritis of the hip joint.

Before determining the advisability of subtrochanteric osteotomy the following requirements must be met:

1. All tractions or splints and fixations (including internal fixation) must be removed.
2. Open ulcers, or decubitus, near the fracture area must be healed.

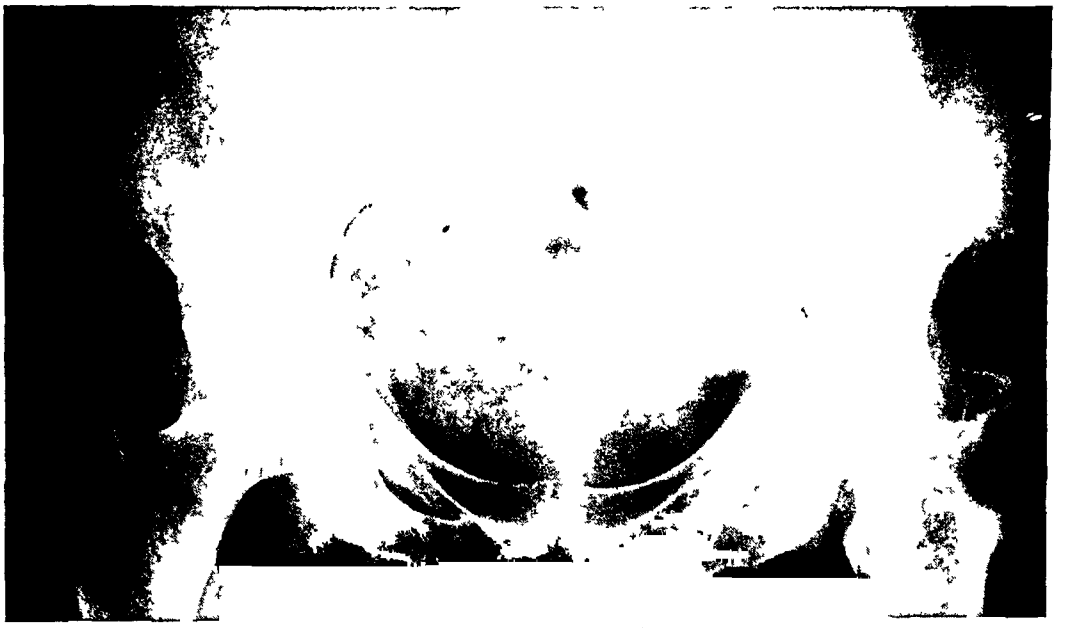


FIG 6—Same hip compared to normal, nine months after subtrochanteric osteotomy. Note the union between head and shaft; the obliquity of the osteotomy; and the healing of the trochanteric portion in good position. There was practically no change in the length of the limb, and the patient walks bearing full weight without pain. Head of the femur as yet shows no evidence of necrosis or breaking down.



FIG. 7.—An autopsy specimen of a hip which had undergone subtrochanteric osteotomy 9.5 weeks previously. The roentgenogram already shows healing of the trochanteric portion, but as yet an incomplete bony healing to the head. Patient passed away from an embolism when he was becoming ambulatory.



FIG. 8.—Photograph of section through the specimen shown in Figure 7. The healing of trochanteric fragments seems quite complete. The head and neck although not bonily united are firmly apposed, and gave promise of bony union in the not distant future, aided by proper weight-bearing.

3. Roentgenologic examination of both hips in a postero-anterior plane and a lateral of the fractured hip must be obtained to determine:
   (a) The amount of absorption of the neck,
   (b) The presence or absence of infection or sequestra or ankylosed joint,
   (c) The rotation of the head fragment,
   (d) The viability of the head determined by its relative density.

If these factors are unfavorable, if the head is completely necrotic, one of the reconstruction operations on the hip may be the best procedure, especially in patients under 60 years of age. Although union to a dead head might be obtained by osteotomy, it would take, at best, a long time to establish revitalization and bone substitution of the head. This might never follow and thus lead to crushing down of the head with all its sequences after weight-bearing was allowed. The patient might not survive the long drawn-out process of rebuilding the head of the femur, and so derive no benefit from the procedure.



FIG. 9.—Shows the deformation of the Steinmann pin through the heel in another instance permitting the shaft of the femur to slacken inside the encasement, and thus change the position obtained at the osteotomy eight weeks before. A final bony healing occurred, but with restricted range of motion, without pain. The pin used for the traction and fixation should be sturdy and strong enough to obviate such deformity while undergoing the strain within the plaster support.

If these briefly mentioned conditions are favorable, the patient's general condition unless obviously moribund, the fear of expected follow up care, his age, and even his weight, may be discounted. Preliminary traction on the leg by means of a sturdy steel pin inserted through the calcaneus may be helpful in marked overriding of the fracture of the neck. At operation, manipulation on a fracture table with perineal post and foot pieces for traction, is performed to put the fragments of the ununited neck into apposition and to hold them thus with slight abduction of the legs — 15°-20° as a rule. This is securely held by means of fixed traction to the foot pieces of the fracture table, using the skeletal traction on the injured side, with the toes straight up or even slightly inverted. The reduction thus obtained at the neck of the femur is checked by roentgenograms in two axes, anteroposterior and lateral.

A short incision 3 to 4.5 inches long is made on the lateral surface of the injured hip, starting at the greater trochanter, passing down directly in the long axis of the femur. The skin, fat, fascia and thin muscle layer are cut through. The upper end of the femur is exposed and a point selected about

two inches below the tip of the greater trochanter. Into the cortex of the femur, at this point, a steel marker—a pointed wire or Steinmann pin—is inserted at right angles to the long axis of the bone. Another antero-posterior roentgenogram is made to determine the position of this marker in relation to the lesser trochanter of the femur. If it is placed at a satisfactory level so that the osteotomy near it will cut through the trochanteric portion of the bone just above the lesser trochanter, a broad-bladed chisel is then driven through the femur with a heavy hammer in a slightly oblique upward direction. This cuts the shaft of the bone completely free from the head and trochanter and yet the shaft lies in traction and in slight abduction in relation to the long axis of the body. The shaft fragment is then shoved inward through the small wound as far as it will go or the whole thigh can be bumped in by the operator's body-weight, the leg traction remaining firm. A roentgenogram is made to confirm this inward displacement of the shaft almost directly under the head of the femur and the wound is closed in layers.

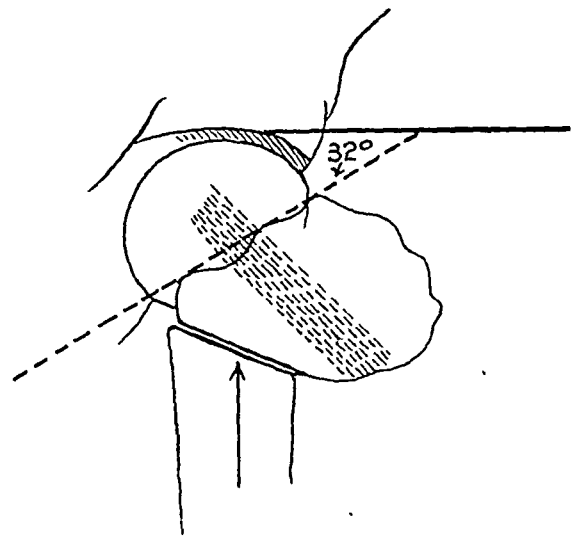



FIG. 10.—King's method of fixation by bone transplant introduced through the neck into the head followed by the osteotomy. This aims to prevent a slipping out of the shaft fragment and a better retention of the trochanteric fragment. The result of this step is doubtful in my mind as the healing between the head and trochanteric portion depends solely upon the bone transplant.

A light plaster-of-paris encasement is then applied enclosing the whole operated upon leg and firmly pressing against the skeletal traction in the heel embracing also the good leg almost to the knee, which is left free. The time of the operation is short, cooperation of the roentgenological work expedites it.

Eight weeks immobilization during which the patient is turned onto a prone position twice a day suffices for union, not only of the osteotomy but quite marvelously of the ununited neck. The bone has been restored to a weight-bearing axis and healing thus favored—a seemingly simple solution.

One may use pins, such as the Neufeld, Preston or Austin Moore pin, and others, which pass through the neck and head with an angled extension screwed onto the shaft to hold this inwardly placed shaft of the femur. I have found them unnecessary. For osteosynethesis King[1] used a pin and fibular transplant through the trochanter into the neck and head to hold these fragments together before performing the osteotomy. This is very useful to prevent slipping up of the shaft. I cannot find, even in the oldest patient, that the eight weeks splintage acts untowardly if proper nursing care is given. This care must be first class and planned before operation. Pin deformation (through the calcaneus) accounted for the only instance of

mechanical failure I have encountered. The attempt on this patient, consequently, did not result in the ideal length and use of the hip joint. The transfixion pin for the skeletal traction through the heel must be strong enough to stand the traction strain of holding the leg in full length during the operation and thereafter until bone healing appears. After the pull of the fixed traction on the table is relaxed following operation, this stress is taken up by the plaster dressing pressing against the pin, with counter pressure up on the head of the tibia and the pelvis above. It must maintain the





FIG. 11 FIG. 12

FIG. 11.—Healing of the trochanteric portion of the femur to the shaft after 9.5 weeks. About six diameters magnification. The formation of new bone between the two bony surfaces is apparent.

FIG. 12.—Beginning healing after 9.5 weeks between the surface of the subtrochanteric osteotomy and the head of the femur. Some of the osteoid tissue has washed out in making the section, but the effort at bony union is starting and the vascularity promised final body union.

pressure which is augmented soon by the pull, inside the plaster, of the muscles from torso to thigh, or even leg, which becomes a very powerful traction. If the shaft fragment tends to slip up and outwards, the axis of its application to the head and neck of the femur is changed, and the hoped for result may be a partial failure. Such a hip, however, may obtain bony union, become painless and permit weight-bearing, but with greatly restricted range of motion.

As a rule, astonishingly enough, the incisions and fractures heal even in the aged. After subtrochanteric osteotomy the hip, though somewhat restricted in all motions, soon bears weight and resumes pleasing function.

The knee stiffness incidental to plaster confinement gradually wears off under physiotherapy, and the patient proceeds to stable ambulation.

One fatality in ten patients, varying in age from 62 to 78 years, operated upon in this, and other hospitals, has occurred. Death resulted from pulmonary embolism in the tenth week after operation, as the man was about ready to leave the hospital. The remaining nine patients are ambulatory, some with, some without canes, no hip pain, a slight amount of shortening of the injured leg. No patient has yet shown necrosis or breaking down of the head of the femur, possibly because not more than three years has elapsed for any one of them. Following their ununited fracture of the neck of the femur, they have been restored from a threatened invalidism to activity.

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[1] King, Thos.: Closed Operation for Intracapsular Fracture Neck of the Femur. Brit. J. Surg., 26, 921, 1939.

# INCISIONS IN SURGERY OF ANEURYSMS

## WITH SPECIAL REFERENCE TO EXPLORATION IN THE ANTICUBITAL AND POPLITEAL FOSSAE

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IN THE SURGERY OF ANEURYSMS and other lesions of arteries it is important that one use an incision which permits easy and complete access to the vessels involved. Furthermore, it is important that the incision be so placed that, by lengthening it, the vessels distal and proximal to the site of suspected pathology are accessible without difficulty. These considerations do not obviate in any sense, however, the advisability of using skin incisions which yield a good plastic result, which do not cross normal skin folds, and which minimize the hazard of keloid formation, scarring and contracture, provided that such incisions sacrifice nothing essential in regard to exposure of the vessels. In my experience with the operative treatment of over 260 aneurysms and arteriovenous fistulae, rarely, if ever, have I found that a properly placed plastic incision offers any real limitation in exposure of the vessels. It is the purpose of this communication to discuss this general problem and particularly that of exploration in the popliteal fossa and in the anticubital space.

### THE POPLITEAL FOSSA

It has been common practice to explore the popliteal vessels through a longitudinal incision which crosses the popliteal crease. A high percentage of patients who have been subjected to such an incision subsequently develop heavy scars or keloids, contracture, and, in some instances, ulceration. This sequela is disabling and its remedy by plastic procedures is time-consuming and not always successful. Such incisions are, I believe, entirely unnecessary in exposing the popliteal vessels.

For lesions of the femoropopliteal and first portion of the popliteal vessels, a longitudinal anteromesial incision extending down to the knee is used. When the thigh is externally rotated and the knee is flexed, the sartorius is relaxed and easily retracted. The femoral vessels are accessible proximal to the point where they pass under the adductor tendon and the popliteal vessels where they emerge beneath this tendon. Exposure of the popliteal vessels by this incision is illustrated in Figure 1.

When the lesion exists more distally, one of the incisions illustrated in Figure 2 is employed. The essential feature here is a transverse incision across the popliteal space in one of the popliteal creases. Indeed, a simple transverse incision will occasionally suffice, particularly when a large saccular aneurysm is approached by the intrasaccular route under tourniquet. Generally, however, the incision must be extended upward along the mesial aspect

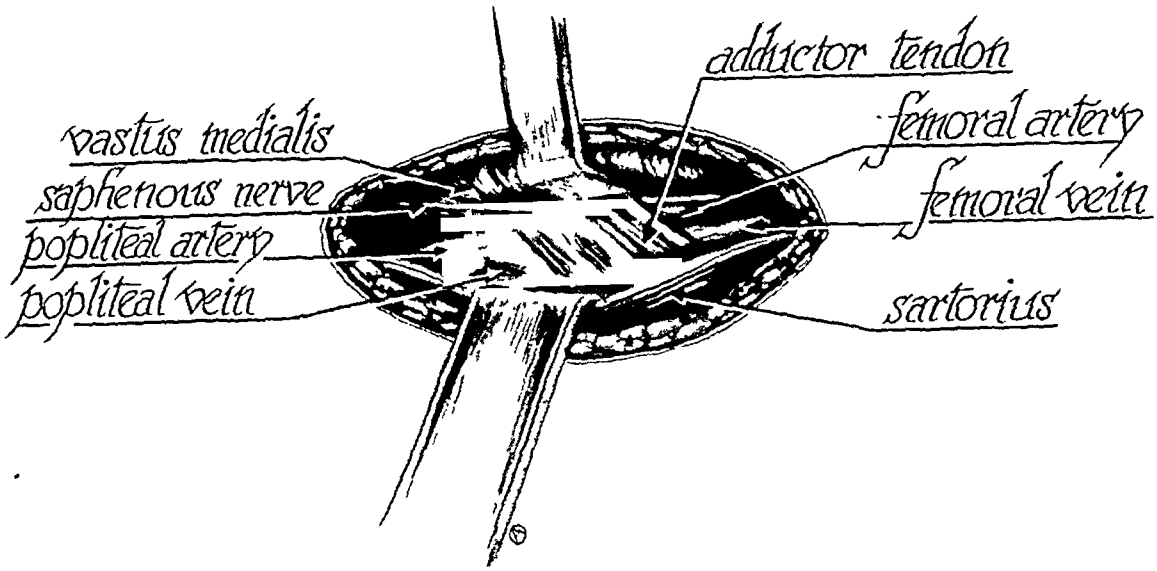



FIG. 1.—Exposure of the distal portion of the femoral and the first portion of the popliteal vessels.

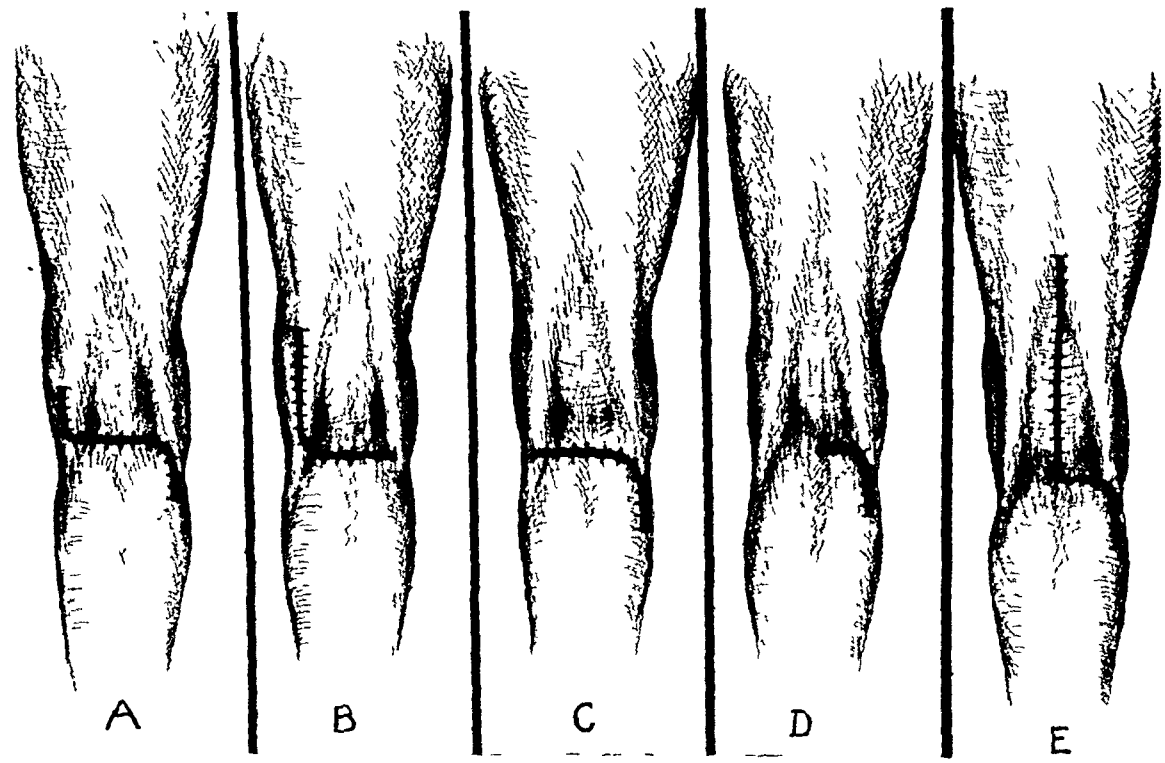



FIG. 2.—Skin incisions used in exploring the popliteal vessels:

(A) The incision used when the lesion exists in the popliteal vessels in the mid-popliteal space.
(B) The incision used when the lesion is higher in the popliteal fossa.
(C and D) Incisions used for exploring the distal popliteal vessels.
(E) A modified incision useful when associated nerve lesion requires exploration.

of the thigh and downward along the lateral surface of the leg (Figs. 2A and 3A). The resulting exposure is quite as good, perhaps better, than with the use of a midline longitudinal incision. The skin flaps are reflected and the fascia is incised longitudinally in the midline. The biceps is retracted laterally; the semimembranosus and semitendinosus mesially. The tibial and peroneal nerves are identified without difficulty. The vein and the artery are accessible. The exposure obtained is illustrated in Figure 4. If the lesion is high in the popliteal space, an L-shaped incision extending across the popliteal space and up along the mesial aspect of the thigh is sufficient (Figs. 2B and 3B). If there is an accompanying nerve lesion which requires surgery this procedure is facilitated if the longitudinal limb of the

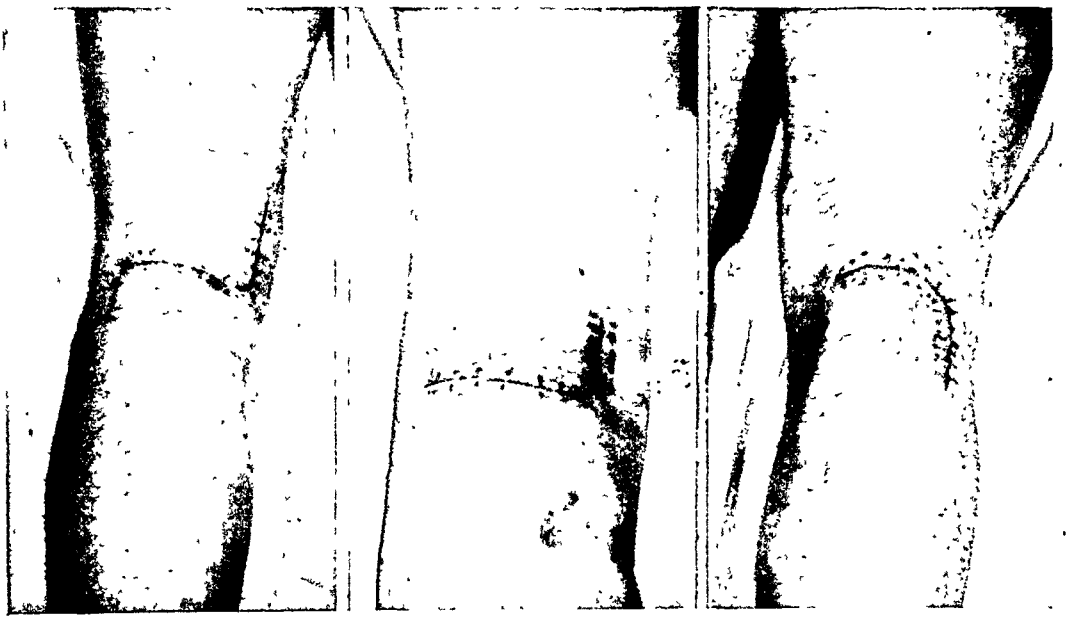



FIG. 3.—Photographs of wounds in popliteal space:

(A) Arterial aneurysm in midpopliteal fossa was excised.
(B) Arteriovenous fistula just proximal to midpopliteal space was excised. Often the upper limb of incision must be extended farther up the thigh.
(C) Arteriovenous fistula of distal portion of popliteal vessels was excised.

incision is placed in the midline rather than along the mesial aspect of the thigh (Fig. 2E).

If the aneurysm or fistula is in the distal portion of popliteal space, exposure is difficult by retraction or division of the heads of the gastrocnemius muscle and such a procedure entails a definite hazard since the tibial innervation of the gastrocnemius, the plantaris and popliteus muscles may be injured. Exploration is made easy by using an L-shaped incision which crosses the lateral half of the popliteal space and extends downward along the posterolateral aspect of the calf (Figs. 2C, 2D and 3C). The fascia is divided beneath the skin incision. The lateral head of the gastroc-

nemius, along with the plantaris, is easily elevated and retracted upward and mesially. The popliteal artery and vein and the tibial nerve are then brought into view and can be followed as they cross over the popliteus muscle and pass through the tendonous arch of the soleus muscle (Fig. 5). If the lesion exists in that portion of the vessels covered by the soleus muscle, the skin incision must be extended down the leg. Exposure of the

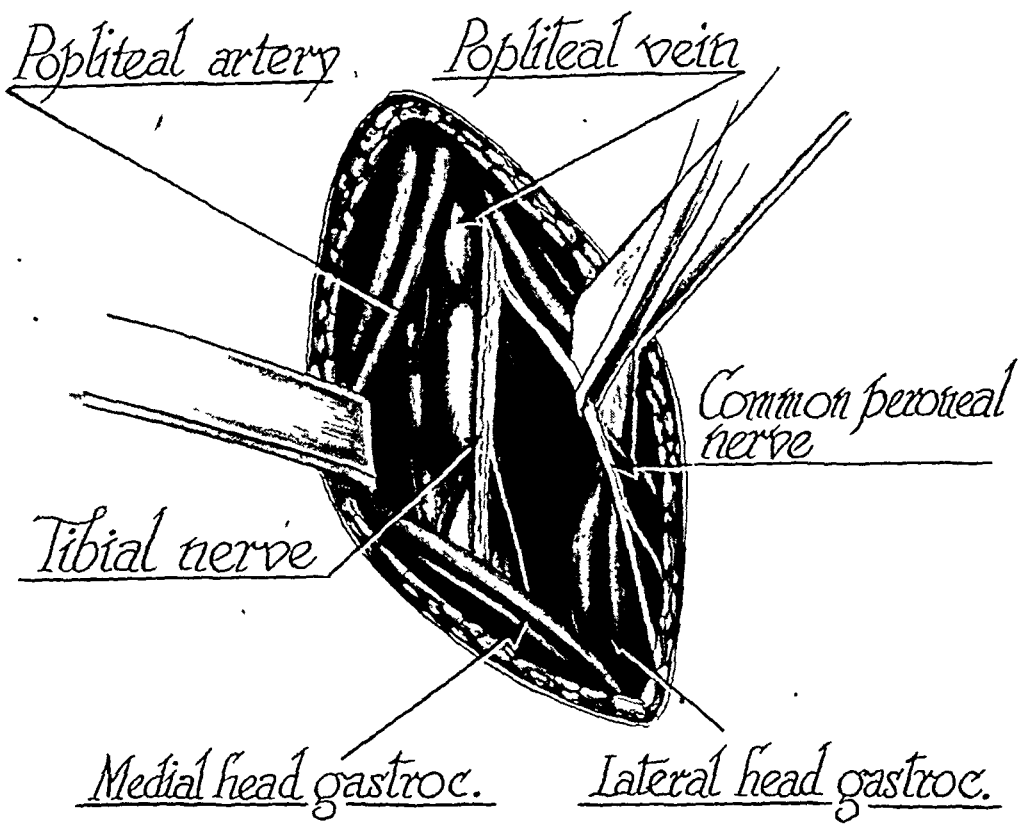



FIG. 4.—Exposure of the popliteal vessels in the popliteal fossa. The biceps muscle is retracted laterally above and the plantaris and lateral head of gastrocnemius below. The semimembranosus and semitendinosus are retracted mesially above and mesial head of gastrocnemius below. Tibial and common peroneal nerves are isolated and protected. Ligatures are illustrated about the artery and vein proximal and distal to the fistula.

vessels generally necessitates division of the lateral fibers of the soleus attached to the fibula, with or without division of that portion arising from the head of the fibula. Sometimes the vessels can be exposed satisfactorily by incising the muscle longitudinally directly over the vessels.

Incisions such as have been described have been found to be perfectly adequate, and good healing without scarring or contracture has been obtained in all cases. The incision for exposure of the femoropopliteal or proximal popliteal vessels has been used in 24 cases. The various modifications for exposure of the vessels in the popliteal space itself have been

used in approaching 25 aneurysms and also in one case of hemangioma. Aneurysms of the distal portion of the popliteal vessels have been approached through the incision described in 17 cases. In all instances proper surgical treatment of the aneurysm has been carried out without difficulty.

### THE ANTICUBITAL FOSSA

The brachial vessels through most of the length of the arm are easily approached through longitudinal incisions overlying their course, and such incisions are entirely satisfactory. For operations upon the first portion of the brachial vessels, an incision which does not cross the axilla will be described subsequently. For lesions in or near the anticubital fossa it has

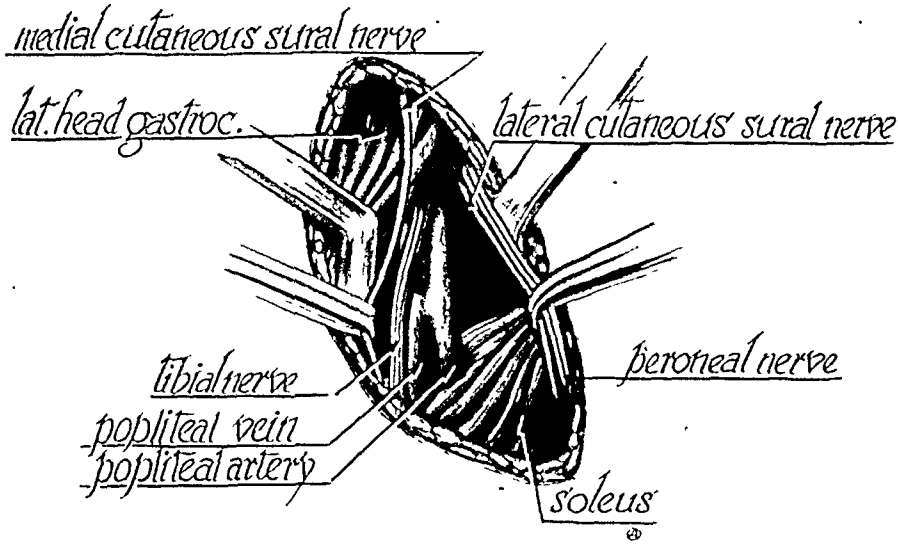



FIG. 5.—Illustration of operative exposure of distal portion of popliteal vessels. Lateral head of gastrocnemius is retracted and vessels and nerve are seen lying upon popliteus muscle and as they enter soleus.

been found very helpful to use incisions similar to those employed in the popliteal fossa. A transverse incision is made across this space following a natural skin crease. It is generally extended upward for a short distance along the anteromesial aspect of the arm and downward along the anterolateral aspect of the forearm (Figs. 6A and 7A). The skin flaps are reflected. The communications between the cephalic and basillic veins are divided. The lacertus fibrosus is severed. The cephalic vein and the lateral antibrachial cutaneus nerve are retracted laterally and the basillic vein and medial antibrachial cutaneus nerve mesially. The brachial artery and vein, as well as the median nerve, then come into full view (Fig. 8). The vessels are easily exposed down to a point below the bifurcation into radial and ulnar branches. If the lesion is high, only a transverse incision extended upward is necessary (Figs. 6C and 7B) and if it is low, a transverse incision extending downward may suffice (Fig. 6D). If the fistula or aneurysm

is suspected to exist in the upper portion of the ulnar vessels, a transverse incision is made across the anticubital space and extended downward along the mesial aspect of the forearm (Figs. 6B and 7C). If a lesion exists in the proximal portion of the radial vessels, it is sometimes helpful to supplement an anterolateral longitudinal incision by curving it across a portion of the anticubital space. Such incisions have been used in the exposure of 11 aneurysms. They have proved entirely satisfactory. Prompt healing occurred in all and in none has there been any scarring or contracture. In a single instance, where the corner of an L-shaped incision was perhaps traumatized at operation, a superficial slough about 1 cm. in diameter occurred, but this did not involve the entire thickness of the skin and epithelized readily.

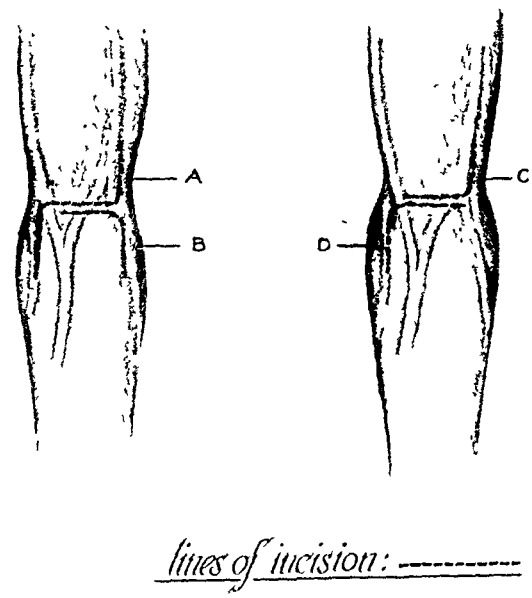



FIG. 6.—Incisions used in exposure of vessels in anticubital fossa:

(A) The usual incision for exposure of brachial vessels in anticubital space.
(B) Incision used when lesion is suspected in proximal portion of ulnar vessels.
(C) Incision used when brachial vessels are involved just proximal to anticubital crease.
(D) Incision used for exploration of distal end of brachial or proximal end of radial vessels.

### THE VESSELS IN THE NECK

Many have felt that exploration of the great vessels of the neck necessitated a longitudinal incision along the course of these vessels. It is well known, however, that such incisions yield scars which are often far from pleasing. Heavy and wide scars, keloid formation, and actual contracture sometimes follow. On the other hand, it has been the general experience that oblique skin incisions following the natural skin creases of the neck result in inconspicuous scars which never cause contractures or deformity. Such incisions properly placed are compatible with perfectly adequate exposure of the carotid artery and the jugular vein. During 16 explorations of these vessels I have found such incisions perfectly satisfactory and have used them invariably except in instances when adequate exposure could be obtained by excision of some preëxisting scar (Fig. 9). One can almost always localize the level of the arteriovenous fistula or aneurysm prior to exploration. If one places the skin incision properly and mobilizes freely the upper and lower flaps, the fascia can be incised along the anterior border of the sternocleidomastoid which is retracted posteriorly, the carotid sheath opened longitudinally, and the vessels exposed adequately above, below, and at the site of the pathology. The vagus nerve can be visualized without difficulty and injury to it avoided.

In three of the four vertebral arteriovenous fistulae which I have treated surgically, scars were present and were excised and modified as the situation demanded. In a single instance of a fistula in the first portion of the vertebral vessels exposure was adequate through a low oblique incision in a skin crease. The localization of arteriovenous fistula and other lesions

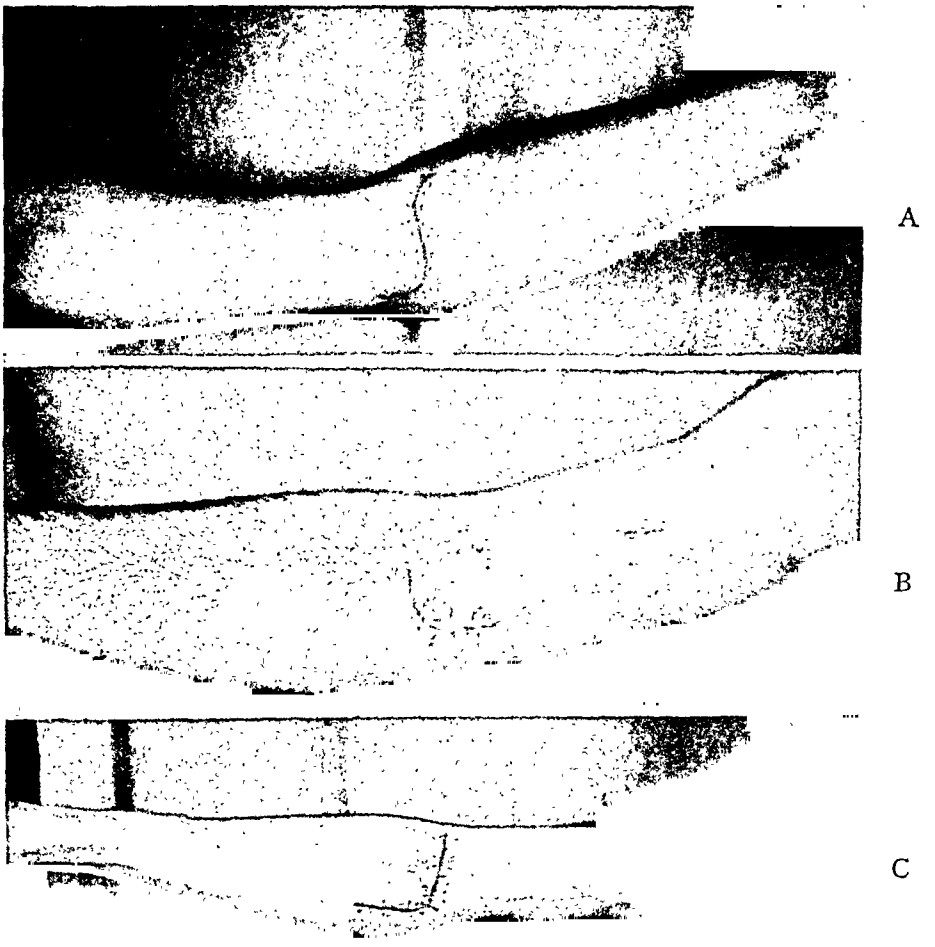



FIG. 7.—Photographs of wounds in anticubital space:

(A) Aneurysm was excised from midportion of anticubital fossa.
(B) Brachial aneurysm just proximal to midanticubital space was excised. Artery was repaired by end-to-end suture.
(C) Arteriovenous fistula at bifurcation of brachial vessels was excised.

of these vessels is exceedingly difficult since one cannot possibly occlude the vessels by digital pressure throughout that portion which lies within or distal to the tranverse foramina. Furthermore, in any operation upon the vertebral vessels, it may prove necessary to expose them both proximally and distally to the intraforaminal portion.

If the lesion is in the very first portion of the vertebral vessels a low oblique incision, permitting resection of the inner third of the clavicle and mobilization of the subclavian vessels if necessary, is perfectly satisfactory. It would be my feeling that a properly placed oblique incision would prove adequate for lesions of the proximal intraforaminal portion of the vessels. Should a situation arise where it is necessary to expose the vertebral vessels between the atlas and the second vertebra, an additional incision could be used. For lesions in the distal part of the cervical portion of the vertebral vessels, where it will be necessary to have wide exposure and to reflect the insertion of the sternocleidomastoid, it may be preferable to use a more or

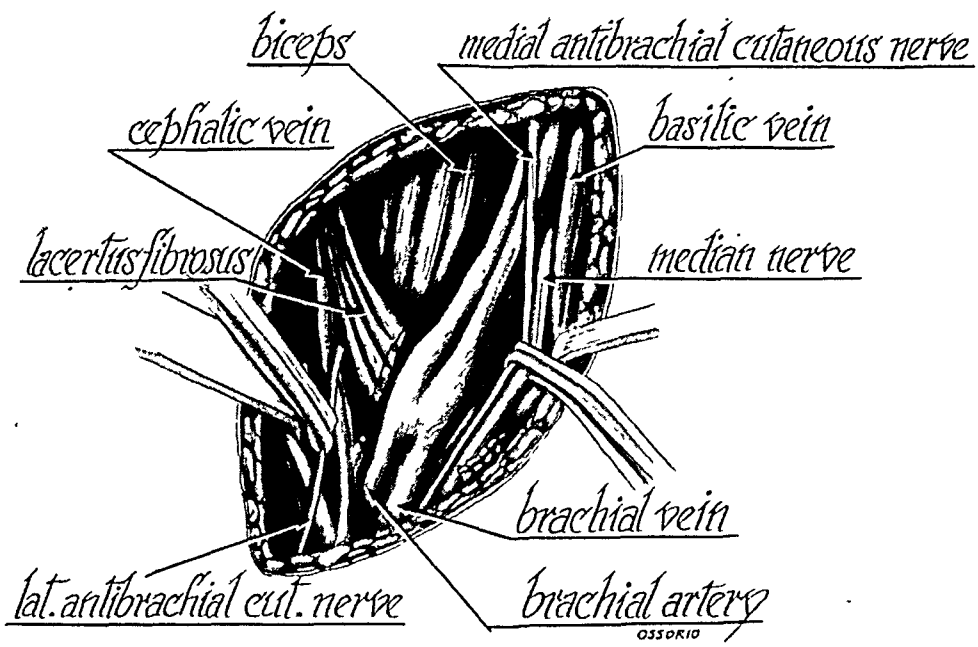



FIG. 8.—Operative exposure of brachial vessels in anticubital space. The communications between basilic and cephalic veins have been divided. Lacertus fibrosus has been severed. The cutaneous nerves and the median nerve are illustrated. A fistula between the brachial artery and vein is shown.

less longitudinal incision. As stated above, my own personal experience is limited to a single instance of a fistula in the first portion of the vertebral vessels, and to three arteriovenous fistulae which were situated in the sixth transverse foramen in which prior exploration had been carried out so that the existing scars were used.

### THE INNOMINATE, SUBCLAVIAN, AXILLARY, AND THE FIRST PORTION OF THE BRACHIAL VESSELS

In exploration of lesions of the innominate and of the proximal portions of the subclavian vessels, the author uses an incision which lies over the inner third of the clavicle and curves downward over the center of the upper portion of the sternum (Fig. 10). When the skin flaps are reflected,

there is ready access to the clavicle, the manubrium, the sternum, and the muscles which are attached to these structures. The inner third of the clavicle is resected subperiosteally, the sternum is divided in the midline down to the level of the second interspace and is transected across at this level. The sternum can then be spread with traction upon bone hooks, or with a rib spreader, and good visualization of the vessels is obtained. The skin incisions give excellent scars.

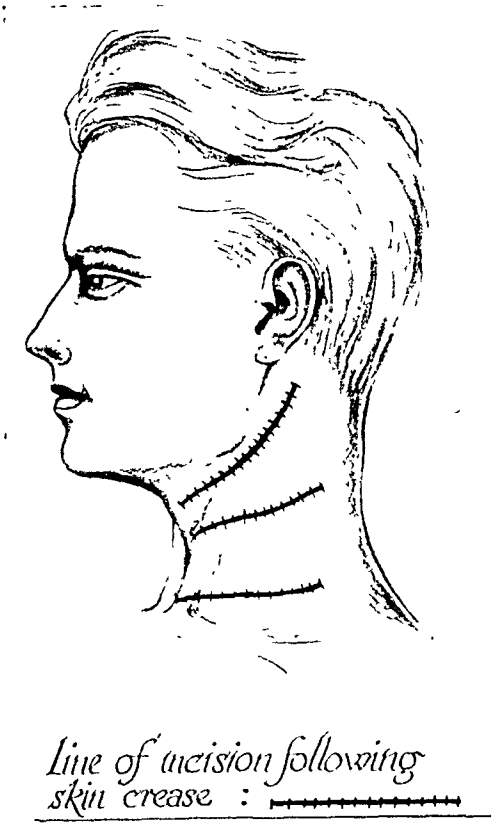



FIG. 9.—Illustration of incisions for exploration of carotid vessels. Often the incisions employed need not be as long as those here illustrated.

For more distal lesions in the subclavian vessels, an incision is made over the inferior border of the inner or midportion of the clavicle. In order to expose the subclavian vessels adequately it is necessary to resect a segment of the clavicle. This is done subperiosteally and the resected part is discarded. At the completion of the operation the periosteum is carefully sutured. Such patients are kept flat in bed for two weeks with their shoulders held well back. During the third week they are allowed up but are encouraged to spend a considerable portion of time lying on their backs. Very rapidly a firmness appears in the region where the clavicle is missing. Although at the end of three weeks roentgenograms reveal no definite evidence of bone regeneration, on clinical examination one can hardly tell that a clavicular resection has been done. Such patients have normal configuration of shoulders, normal motion, and are entirely comfortable (Fig. 11). Often after three months there is still no evidence roentgenographically of bone regeneration. Most of my own patients have not been observed longer. It is evident, however, that after an interval of six or eight months complete regeneration takes place in the majority of patients. In order to hasten bony regeneration, I am at present investigating the use of bone chips from the resected segment of the clavicle packed into the periosteal bed. The results of this study will be reported subsequently.

Mayfield[2] has observed a patient in whom, following periosteal excision of a segment of clavicle, excessive bone regeneration had occurred at the site where the periosteum was divided tranversely and sutured. No pressure symptoms were present in this individual, but, by analogy with cases of

large callus following fractures of the clavicle, it is possible that such bone regeneration might conceivably cause pressure upon the brachial plexus. Therefore, when it is necessary to transect the periosteum in order to facilitate exposure, it is advisable to do this in such a manner that the incision does not overlie the plexus.

In a single instance in which the resected clavicle was reinserted and fixed in place with wire sutures, the patient had a great deal of pain, union did not occur promptly, and the replaced portion of the clavicle was subsequently removed with relief of symptoms. We have seen a number of patients who were operated upon elsewhere with clavicular resection and replacement of the fragment or with division and resuture who have had

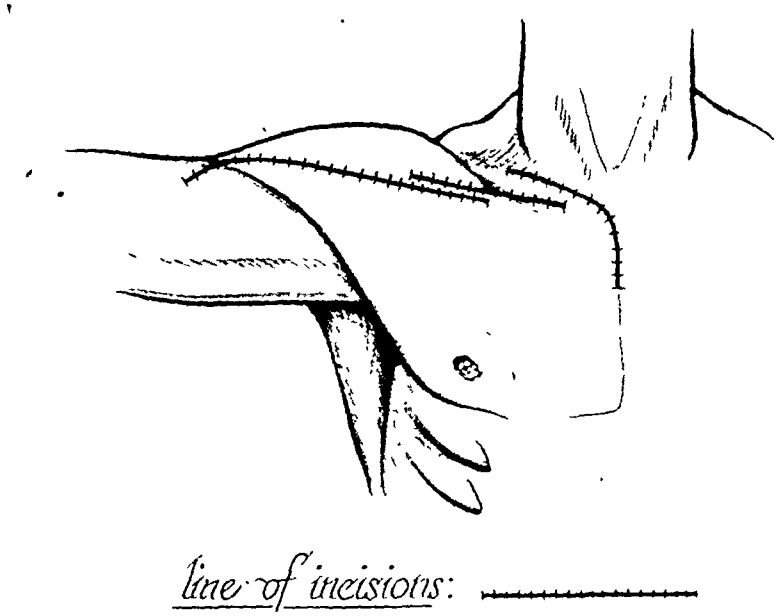



FIG. 10.—Illustration of incisions for exposure of innominate, subclavian, and axillary vessels.

difficulties of one sort or another. One had an osteomyelitis, another a painful malunion, and a third subluxation of the sternoclavicular joint. It is my conviction that where resection of a portion of the clavicle is essential, it is best discarded, and a careful reapproximation of the periosteum carried out, or that it be replaced with bone chips packed in the periosteal bed, and I am in complete agreement with Holman[1] that excision is preferable to division.

For lesions involving the axillary vessels, an incision is made over and parallel to the upper fibers of the pectoralis major, beginning in the region of the mid portion of the clavicle. In general, if the first half of the axillary vessels is all that needs be exposed, nothing more is necessary than to separate the upper fibers of the pectoralis major through such an incision and either to retract or transect through its insertion the pectoralis minor.

If the distal portion of the axillary vessels has to be explored, the incision continues out over the insertion of the pectoralis major and this muscle is divided through its tendonous insertion (Fig. 10). The incision described for the first portion of the brachial vessels is often adequate for the region of the distal end of the axillary vessels.

This incision begins over the insertion of the pectoralis major, curves down the inner aspect of the arm distal to the axilla, down to the region of the neurovascular bundle, and thence down a short distance over the course of these vessels (Fig. 12). When the skin flaps are reflected, the distal portion of the axillary vessels and the first portion of the brachial vessels are readily accessible. Incision through the axilla is thus avoided.

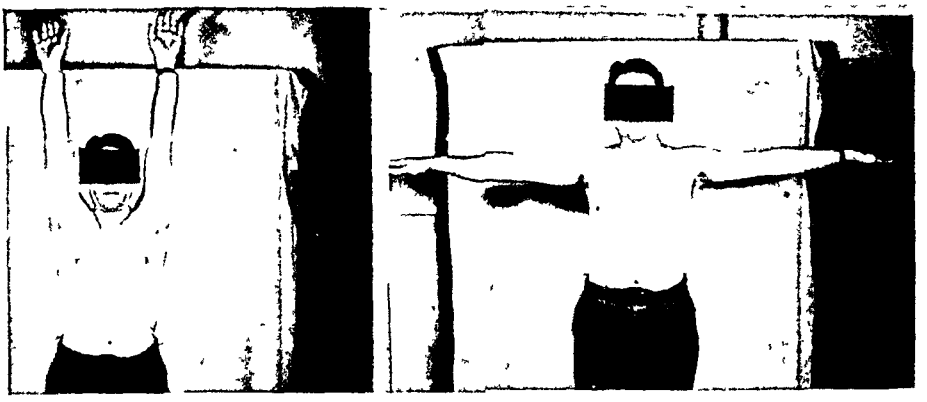


FIG. 11.—Photograph of patient after excision of fistula between internal mammary artery and innominate vein showing normal range of motion a month after resection of inner third of clavicle.

The disastrous results of incisions through the axilla—the keloids, heavy scars and disabling contractures—are familiar to all.

Such incisions for exposure of the subclavian, axillary, and first portion of the brachial vessels have been used in over 50 instances. The results have been gratifying. Adequate exposure has been obtained and proper surgical treatment of the aneurysm has been carried out without undue difficulty. Where concommitant nerve lesions have existed adequate exposure of these structures has been possible. No contractures have resulted. Where the tendonous insertion of the pectoralis minor or major has been divided, repair has resulted in good muscular function.

### EXPOSURE OF OTHER PERIPHERAL ARTERIES

In general, exposure of other arteries in the upper and lower extremity can be carried out without difficulty by using properly placed longitudinal incisions. Such incisions cross no skin creases and do not result in any difficulty. For lesions of the common femoral artery and occasionally for the proximal portion of the femoral or profunda femoral artery, an oblique incision just below Poupart's ligament is preferable. If a lesion is found

to be too high to permit adequate exposure without proximal extension of a longitudinal incision, it is preferable to curve the incision up along the inguinal fold rather than to cross the crease.

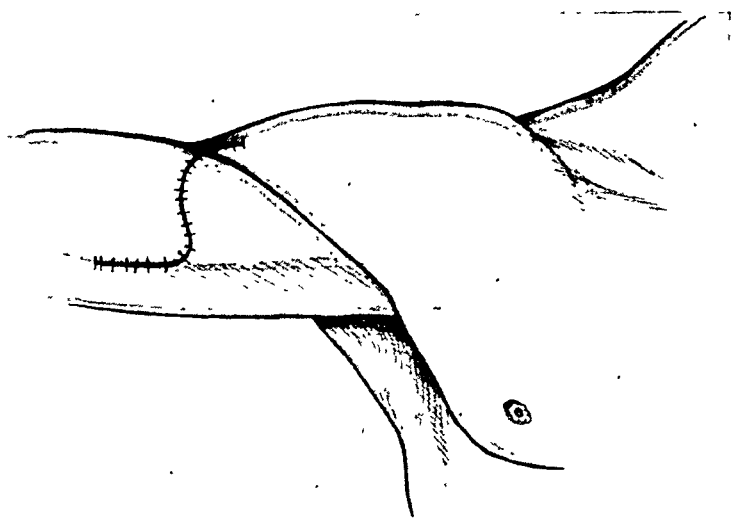


FIG. 12.—Illustration of incision for exploration of distal portion of axillary and first portion of brachial vessels.

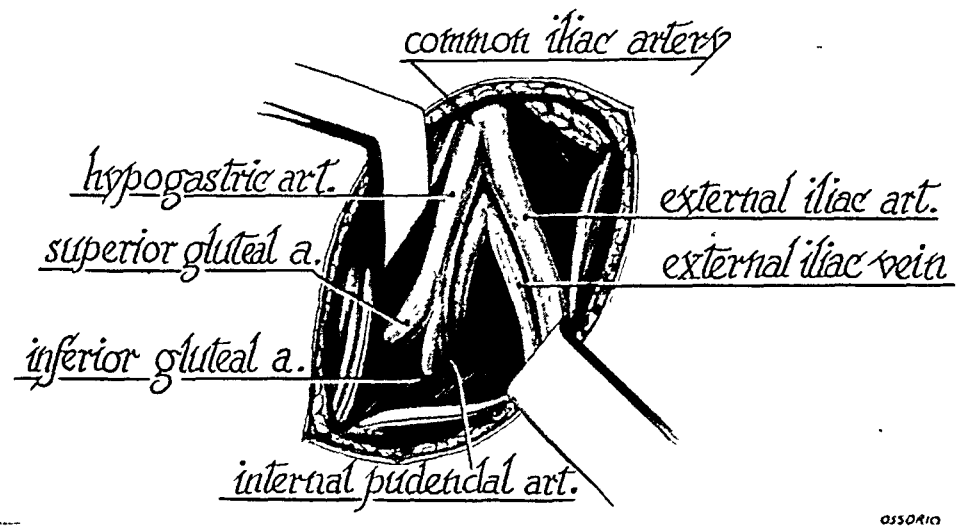



FIG. 13.—Operative exposure of left iliac and hypogastric vessels. The incision is a muscle-splitting extraperitoneal one. The ureter is retracted with the peritoneum.

The iliac vessels are best approached through oblique muscle splitting extraperitoneal incisions. For lesions of the distal external iliac vessels, an oblique incision just above Poupart's ligament is desirable. The fascia of the external oblique is divided, opening the external ring. The internal oblique is divided in the direction of its fibers as is the transversalis fascia. The iliac vessels are readily exposed above the inguinal ligament and the femoral vessels, if necessary, below the ligament. If the situation demands,

the inguinal ligament can be transected and resutured at the close of the procedure. Closure of the wound is carried out much as in a hernia repair. Lesions higher in the iliac vessels or in the hypogastric vessels or their branches are easily exposed through a left lower quadrant muscle-splitting extraperitoneal incision (Fig. 13). The external oblique, the internal oblique, and the transversalis are split in the direction of their fibers. The peritoneum is stripped back from the pelvic wall and retracted mesially. The ureter is retracted with the peritoneum. Good visualization of the common iliac, the external iliac, and the hypogastric vessels and their branches can be obtained.

DISCUSSION.—In their legitimate desire to obtain easy and adequate exposure of vessels, it has been the custom of many surgeons to use incisions directly overlying the course of the involved vessels without regard to the crossing of natural creases and skin folds. When such incisions cross the popliteal fossa, the anticubital space, or the axilla, and when they transect the normal skin creases of the neck and groin, they are frequently followed by cosmetically unpleasing scars and not uncommonly by disabling contractures. In the author's experience, it is rarely, if ever, necessary to use incisions other than those which are sound from a plastic standpoint. A number of specific problems have been discussed, and methods which have proved satisfactory described. By use of such properly placed incisions, adequate exposure can be obtained without risk of keloids and contractures. The question may be asked whether ischemia of the distal flap may sometimes follow transverse incisions across the popliteal fossa and the anticubital space. The author feels that if the circulation is adequate for surgery of the aneurysm, the distal flap will have adequate blood supply.

SUMMARY

The problem of skin incisions in surgery of aneurysms is discussed with particular reference to the approach of the vessels in the anticubital space and popliteal fossa.

The author wishes to express his appreciation to Cpl. A. Ossario who made the illustrations.

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**EDITORIAL ADDRESS**

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# CROSS NERVE ANASTOMOSIS IN MAN

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NERVE ANASTOMOSIS OPERATIONS are of common practice especially during war and post-war periods. The technic has attained a standard leading to very satisfactory results. By cross nerve anastomosis is meant anastomosing the proximal segment of a nerve, or part of a nerve, into the distal segment of another, thus, providing the latter with functional activity from the former.

Such a method is well-known to have been applied in the treatment of cases of facial paralysis of traumatic origin where the distal segment of the facial was implanted into the proximal segment of the spinal accessory, but later into the hypoglossal nerve. The operation was applied in a fair number of cases by different surgeons, and over a period of many years, with varying opinions as to the final degrees of functional success. The results did not satisfy its originator, Sir Charles Ballance, who, after a long series of experiments in America with Dr. Arthur Duel, decided to give up his operation, recommending instead the use of degenerated nerve graft, and reporting results which were far superior. The causes of failure in facial cross nerve anastomosis will be discussed later.

Cross anastomosis of nerves is not a new procedure. Animal experiments on reciprocal cross nerve anastomosis were done more than a hundred years ago. The first experiments were those by Flourens, in 1827, who operating upon cock wings, cut the flexor and extensor nerves, implanted one segment into that of the other, and *vice versa,* with good functional recovery. Kilvington and Kennedy performed analogous experiments upon the dog, crossing flexor and extensor nerves, and also obtained good functional recovery.

The case reported herewith is believed to be the first instance where cross nerve anastomosis of peripheral nerves in limbs was applied in man.

**Case Report.**—S. H. A., male, age 35, was admitted to the University Hospital, Alexandria, August 3, 1943. The patient was a musician, playing the clarinet, an instrument requiring fine finger movements. He complained of marked disability of his right hand, which incapacitated him to such a degree that he had to find another more sedentary occupation.

Eight months previously, while working in a cabaret, a quarrel amongst the attending soldiers took place. He received an injury to his right forearm, by a piece of broken bottle. He bled considerably, and was taken to the hospital, where an operation was performed. The wound became septic, but after a long interval it became completely healed, leaving a disabled hand. Since then the condition progressed, and became worse. He developed a trophic ulcer on the thumb, and occasionally burned his fingers while applying an hot water bath, which had been recommended.

Examination revealed marked deformity of the right hand, which tended to be a claw-hand, with a small indolent ulcer on the pulp of the thumb. A wide, adherent scar was present on the volar surface of forearm, or its middle. Testing the nerve function in the locality proved that there was a complete severance of the median nerve with total sensory loss, accompanied by wasting and paralysis of the short thenar muscles. The

ulnar nerve, however, showed partial function. Although the hypothenar and interosseous muscles were wasted and paralyzed, yet its sensory functions were partially present. The radial pulse was absent. The muscles showed R. D.; and the case was diagnosed as complete severance of the median and partial severance of ulnar nerves. After such a long history operation was advised but the patient was given a guarded prognosis.

*Operation.*—A long incision at the medial side of forearm was made to expose the ulnar nerve segments first. The muscles under the scar were markedly adherent to skin and to each other, and at once it was apparent that direct exposure of the cut ends at the site of injury would be most difficult. Thus, the upper segment of the ulnar nerve was exposed high up and followed downwards to the cut end, which was found firm and bulbous. Turning to the lower segment near the wrist, it was followed upwards. As the dissection approached the site of injury, it was observed that the nerve had shifted laterwards, continuing upwards and, strangely enough, it was found connected and firmly sealed to the upper segment of the median nerve. On searching for the distal segment of the median nerve, its upper cut-end was found to be free. This at once explained that the certain amount of function which existed in the ulnar nerve distribution in the hand was, in fact, due to this cross anastomosis of the upper median and the lower ulnar, *i.e.*, the patient had a median-ulnar nerve, which we may call here trunk A.

Considering that the union was firm, that there was a certain amount of function, and that further improvement in the regeneration of this accidental trunk was expected, and, considering the poor results in nerve suture in case of ulnar and median nerves in particular, it was decided, after consulting with Prof. Abbas Hilmy, to leave the existing cross anastomosis as such, and to perform a new one by joining the lower median to the upper ulnar. The anastomosis was performed and a fairly good bed for it was prepared deep to the flexor digitorum sublimis, and this trunk may be termed trunk B.

On account of the marked fibrosis of the cut-ends, a good length of each had to be excised and, to obviate tension, the wrist joint had to be flexed for some weeks in plaster. The postoperative progress was satisfactory; the ulcer on the thumb rapidly healed; and the patient was given electrotherapy.

He was discharged, and disappeared for a long time, until he was recently seen, almost two years after operation, when no further improvement could be expected.

He was satisfied by the progress he attained. Of course, no one expected he would be a musician again, but he found his hand most useful compared to the previous complete disability. On examination, it was found that his sensory functions had been fairly regained. Pinprick is well-felt with a slight flur. Sense of touch, tactile localization, and the discrimination test of single and double stimuli were all present, but slightly impaired. The short thenar muscles supplied by the new ulnamedian trunk B, formed by the secondary suture, showed fair recovery, and, although the size of thenar eminence continued to show some wasting, yet they worked the thumb very satisfactorily. Those supplied by the old trunk A, formed by the primary suture, eight months previous to the former, did not show the amount of recovery which was expected at the time of the operation, in fact, the motor function in its distribution is now poor.

Discussion.—This case is reported because of the unusual line followed during the operation. It also brings some points of interest and possible practical importance for consideration. The accidental cross anastomosis must have been done by the young doctor on duty, operating when the patient was received in a rush on the night of the accident. He sutured the ends of two separate nerves together with the idea that they were segments of the same nerve, but he eventually built up the new median-ulnar trunk A.

The dangers of, and failures following, primary nerve anastomosis in potentially septic cases have been repeatedly stressed, but it seems that they are

not yet fully appreciated in civil practice. The present case, herewith reported, is an excellent example to demonstrate the poor result of the primary suture applied for trunk A, followed by sepsis, and that of the second suture of trunk B performed eight months later. The latter is definitely superior in its ultimate results. During the operation we thought that regeneration and improvement in trunk A was still in progress, but later examination showed that we were probably wrong, and that its functional recovery had already reached its maximum. The palmar muscles concerned, (hypothenate and interosei) did not show any further marked improvement, whereas, the short muscles of the thumb, whose nerve supply was repaired eight months later, refunctioned satisfactorily. The improvement noticed by the patient of hand function was, really and mainly, due to the refunctioning of the thumb.

It has been already mentioned that cross anastomosis was not a new procedure, and that animal experiments had been undertaken some time ago. Recently, a very interesting investigation was undertaken in the same direction by Aird and Naffziger. They experimented on anastomosing nerves of small caliber into nerves of larger caliber, and described the phenomenon of luxuriant regeneration. In a series of experiments upon dogs, they cut the peroneal and tibial nerves and anastomosed the proximal peroneal into the distal segments of both peroneal and tibial, once immediately, another time after an interval. Simple cutting and resuturing of the same nerve was also done. In every instance they noticed 60 to 90 per cent motor recovery. On taking specimens from the nerves for a comparative fiber count, they demonstrated an increase in the count of 90, 50 and 35 per cent in the three types of experiments, respectively. They concluded that a definite increase in nerve fiber is apparently necessary for reinnervation and regeneration as in the third experiment, and that the increase is still more marked if a small nerve is implanted into a larger one, as in the first two experiments—a phenomenon they called luxuriant regeneration. Consequently, simple section and immediate anastomosis has been recommended for treating partially paralyzed nerves, and that completely paralyzed nerves, as in cases of anterior poliomyelitis, can be supplied with small sections of healthy nerves.

It was stated that the story was not so simple; and in the proper selection of cases there were limiting factors to be considered. If an intact nerve is selected for the anastomosis, the procedure must result in permanent weakening of the muscles previously and normally supplied by that nerve. Hence, only nerves or branches of nerves, the loss or partial loss of which will not cause appreciable disability should be selected. Without proper care in this respect the procedure may conceivably result in as much paralysis as that it is proposed to cure, or worse. Indeed, the use of intact nerve for this procedure does not yet appear to be justified. Because the estimation of functional recovery is so difficult with animals and conclusions based on experimental work frequently require modifications when applied to human conditions, any recommendation in this regard (the use of intact nerves) must be deferred until further data are available, on the degree of functional recovery following this procedure in man.

By recording this case, it is hoped that it would be of some help in the further elucidation of this highly important problem.

The experiments of Kilvington and Kennedy which, in a way, resemble those performed by Aird and Naffziger, are here repeated on the human, with good functional recovery. Still better results can be expected when muscles not so small and of so delicate action as those of the thumb are treated. The very important point to be solved is the choice of nerves or branches of nerves which can be sacrificed without marked disability.

The sacrifice of any nerve must certainly give rise to weakening, however little it may be. If by this sacrifice we aim at regaining function in another paralyzed nerve whose loss is already giving much more marked disability, one can expect, with good reason, that the final functional recovery of the part, as a whole, would be much improved.

The application of such a line of treatment would necessitate, in the first place, a detailed study of functional evaluation of different nerves in every locality, so as to standardize their relative importance when the question of substituting nerves of higher functional value by others of lower functional value is considered.

It has been already mentioned that cross nerve anastomosis in man was first applied by Ballance in the surgical treatment of posttraumatic facial paralysis, and this was in 1895. We are now prepared to discuss why this line of treatment, after being applied for more than 30 years, had proved a failure, that Ballance himself had to give it up and recommend, instead, treating such cases by filling the gap by a degenerated nerve graft.

Claud Coleman, in discussing the relative values of nerve cross anastomosis and nerve graft in cases of facial paralysis, states that both are satisfactory in correcting the appearance of the face during rest. Actually, the muscles of the mouth regain their tone in four to five months, and those of the eye in six months, the maximal regeneration taking place in two years. He does not believe that nerve grafting is superior to nerve anastomosis. He actually states that nerve anastomosis is the only adequate operation for intracranial lesions, *e.g.*, after excision of a cerebellopontine tumor, and recommended the facio-hypoglossal operation. The development of associated movements in face and tongue, which were first thought to be the great drawback of the operation, are easily overcome; tongue atrophy is also of no important significance, as it causes no appreciable interference with speech and deglutition.

Although associated movements, with time and trial, become dissociated, yet the nerve function remains far from normal. The two sides of the face do not work in harmony and on any emotional movement the deformity at once becomes disappointingly prominent.

Even with volitional movements, due to the distortion of regenerating fibrils in nerve suture and graft operations or their indifferent regeneration in anastomosis operation, the nerve works as a functional unit and the face on the affected side works *en masse*.

Older authors state that functional individuality gradually returns and even emotional expression slowly develops, yet they dispute the value of reëducation

of the affected side and advise instead the habit-formation of suppressing the emotional expressive movements on the normal side.

Coleman, although appearing as if he defends the operation of anastomosis, yet by his last statements he is actually approving the disappointment met with by others. In fact, nerve graft operation is definitely more both anatomic and physiologic.

This apparently sad view of nerve anastomosis operation in man is here presented to state that the face and limbs should not be compared in many respects, and operative results should not be the same in both. Although the face and hand can be compared to each other from the point of view that each comprises a number of small muscles concerned with fine movements yet they differ in a very essential fact, *i.e.,* bilateral symmetrical emotional expressions do not exist in the case of hand. Volitional movements in the face return *en masse* and, as mentioned before, only undergo individual dissociation after a fairly long time of reëducation. In the case of the hand, functional individuality developed fairly early and the patient's thumb worked almost exactly as a normal thumb.

If this is the result of operation in such a specialized part as the hand, still better results can be reasonably expected when the method is applied to larger muscles of less specialized action, as in the arm, foot, legs, and thighs.

Thus, where nerve anastomosia did not fully succeed in facial paralysis, there is good reason to hope that it can succeed in paralysis of other peripheral nerves in such conditions as anterior poliomyelitis, possibly with results in the vicinity of perfection. More and more work in this field is definitely needed, and there is every hope that it will be generously rewarded.

SUMMARY

1. A case is reported where, after a trauma, an accidental cross nerve anastomosis, median to ulnar, was performed, and at a subsequent operation another one was done, ulnar to median.

2. Fairly good results can be expected by such a procedure when applied in limbs, not to be compared with the disappointment met with in treating facial paralysis by faciohypoglossal anastomosis.

3. According to the clinical result obtained in the case reported, previous animal experiments and the phenomenon of luxuriant regeneration referred to, it is hoped that good function-recovering would be obtained when some small normal nerves of low functional value are sacrificed to provide activity for paralyzed larger nerves of greater functional value.

I wish to acknowledge, with deep thanks, the criticism and help of Prof. Abbas Hilmy in preparing this paper; and also thank my colleague Dr. M. Naïn for his help.

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# BRIEF COMMUNICATION

## FOREIGN BODY IN THE COLON

HOWARD R. DUDGEON, JR., M.D.
WACO, TEXAS

I wish to report a rather unusual case that was seen by me at the Providence Hospital of Waco, Texas. It is a fairly common occurrence for foreign objects to be introduced into the rectum or urethra for sexual purposes, but these are usually of small size. In the present instance the object was very large and was forced into the patient against his wishes.



FIG. 1.—Roentgenogram showing the bottle as it appeared in the descending colon. The actual size of the bottle is marked on the film in inches. On removal, it was found to be an ordinary olive bottle, 4 x 2 inches in size.

**Case Report.**—F. G., white, male, age 29, was carried into the hospital at 2 P. M., complaining of a foreign body in rectum. He states that he was taken out into the country by four men and that he was held and some object was forced into his rectum. It was very painful at the time and is causing him some pain now. He says that he is able to feel a mass in the left side of his abdomen, which is the object introduced. This was done last night.

About six weeks ago this same man was taken out in the country and an attempt was made to castrate him. This was done by some unknown men; at least the patient will not identify them to the police. At this time, no harm was done to the patient's testicles and the wound in the scrotum was repaired. The patient later shot a man, killing him, and he is now under indictment for murder.

*Physical Examination.*—The patient does not seem to be seriously injured or in pain. Head, neck and chest are negative. In the lower left quadrant of the abdomen, at the level of the crest of the ilium, there is a palpable mass the size of a hen's egg. The mass is definitely intra-abdominal. There is no tenderness, rigidity or distention of the abdomen. When pressure is made on the mass the patient states that he has a desire to defecate. Rectal inspection shows no abrasions of the anus or laceration of the sphincter. Digital examination is negative.

The patient was taken to the operating room and a proctoscopic examination made. The proctoscope was introduced well past the rectosigmoid junction and nothing was found. However, as the patient was very certain that he had something in his rectum and as there was an unexplained mass in his left side, a roentgenogram of the abdomen was made.

We were greatly surprised when the film showed a well-defined bottle, about 4–5 inches long, in the distal part of the descending colon. (The bottle was radiopaque due to the lead used in the manufacture of the glass).

*Operation.*—Under a spinal anesthesia, an attempt was made to remove the bottle by inserting forceps through a sigmoidoscope. Even with this instrument we were unable to reach or even see the bottle. Finally, we were forced to open the abdomen and perform a colotomy for removal of the bottle. The bottle was found to be four inches long and two inches across the mouth. It was located in the distal part of the descending colon. The colon was closed and the abdominal incision drained.

The patient made an uneventful recovery and was discharged from the hospital on the eighth postoperative day. There was no fistula formation, and he is completely recovered, four months after the operation.

DISCUSSION.—The best way to have removed the bottle would have been through the rectum, but we were unable to do this. Opening the colon can be a dangerous thing to do, but luckily no complications developed. This patient did not have any fecal drainage from the wound and no wound infection. He was operated upon before the sulfa drugs were in common use; so he received no sulfadiazine or any of the others.

## SUMMARY

The case history has been presented of a man with a foreign body in the colon which was introduced against his will, the treatment and the end-result.

# ANNOUNCEMENT

## THE PASSANO FOUNDATION AWARD

Selection of Dr. Ernest W. Goodpasture, Professor of Pathology and Dean of the School of Medicine of Vanderbilt University, Nashville, Tennessee, as the 1946 recipient of the Passano Foundation Award is announced by the Board of Directors of the Foundation. Presentation of the $5,000 cash award was made at an appropriate ceremony in historic Osler Hall of the Medical and Chirurgical Faculty of Maryland, in Baltimore, on the night of May 15th.

The Foundation, which was established in 1944 by the Williams and Wilkins Company, Medical Publishers, of Baltimore, proposes to aid in any way possible the advancement of medical research, especially research that bears promise of clinical application. For the encouragement of such research the Foundation has established the award as one of its activities.

Dr. Emil Novak, Associate in Gynecology in the Johns Hopkins University Medical School; Dr. Nicholson J. Eastman, Professor of Obstetrics in the Johns Hopkins University Medical School; Dr. George W. Corner, Director of the Embryologic Laboratory of the Carnegie Institution of Washington, represent the medical profession on the Board of Directors of The Foundation.

Following the presentation of the award by Mr. Edward B. Passano, Chairman of the Board of The Williams & Wilkins Company, Dr. Goodpasture delivered an address entitled, "Research and Medical Practice."

Dr. Goodpasture receives the award for his original development of the method for propagation of viruses in pure culture by inoculation of chick embryos and for his outstanding contributions to advancement of knowledge of the cell-parasite relationship in bacterial and virus infection.

Prior to Dr. Goodpasture's development of the chick embryo method of propagation of viruses in pure culture, medical research was halted in attempts to study diseases caused by viruses because of the fact that viruses will not multiply in culture media as do bacteria. Therefore, virus cultures could not be made available for research into the mechanism of their reactions.

As a result of Dr. Goodpasture's original discovery, some ten years ago, our knowledge of virus diseases has been immeasurably advanced. New viruses have been identified, the mechanism of virus reactions in the host have been studied and means of protection against many virus diseases have been made possible. Vaccines against several diseases of both man and animal against which little if any protection existed before have now been developed. Defenses against such diseases as fowlpox, smallpox, yellow fever, influenza and typhus fever have been considerably advanced by chick embryo study methods.

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# TRANSACTIONS

OF THE

# AMERICAN SURGICAL ASSOCIATION

MEETING HELD AT HOT SPRINGS, VA.
APRIL 2, 3, 4, 1946

## PRESIDENTIAL ADDRESS

## TREATMENT OF FRACTURES*

WILLIAM DARRACH, M.D.

NEW YORK CITY, N. Y.

A FRACTURE PATIENT is an individual whose normal activities, both vocational and avocational, have been interrupted by an injury. This injury has broken one or more bones. The damage is rarely limited to the bone. Associated soft-part injuries are often of greater importance and need more careful attention than the fracture itself. A fracture of the base of the skull does little harm in itself but the associated hemorrhage may be fatal. A fractured spine requires correction of the deformity and rest during healing but it is the associated cord injury that causes the most serious results. A supracondylar fracture of the humerus is an annoying interruption of a child's normal activities but if a Volkmann's ischemic paralysis develops, perhaps as a result of medical carelessness or ignorance, he may be permanently crippled. A comminuted fracture of the femur may take months to get bony union but even if it heals with but little deformity, it will not be very useful if the patient has a stiff knee and hip. The treatment of fractures involves more than looking after the broken bone.

In considering these associated injuries it is well to differentiate between the primary lesions occurring in connection with the accident and the secondary lesions which occur during transportation, examination and treatment. Not much can be done to prevent the primary damage but a great deal can be accomplished in reducing the secondary damage to a minimum. When a bone is broken and the fragments displaced the periosteum is torn and the

*Address delivered before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

overlying muscles, tendons, fascial planes, nerves and blood vessels, are injured more or less by the traumatizing force and the sharp margins of the bone fragments. Hemorrhage occurs from the bone ends and the lacerated tissues. The blood extravasates into and between muscles and along fascial planes with resulting swelling and tension. Edema follows within the hour, increasing the swelling and tension and interfering with the circulation and the elasticity of the muscles.

Under secondary traumata are included the additional injuries caused during transportation without protective splinting, to the hospital, to and from the Roentgenologic Department, ward or operating room, rough handling during examination, carelessly planned and repeated, manipulative attempts at reduction. Most surgical procedures are two-edged swords and do harm as well as good. The art of surgery lies in doing as much good and as little harm as possible by these procedures. Tight bandages, localized pressure from splints, prolonged immobilization and passive movements contribute to these additional injuries. Most of these secondary traumata affect the soft-parts. Many of them can be avoided or at least minimized. Unless proper attention is paid to these soft-part injuries the main object of treatment will be defeated. This object is to restore to normal, as far as possible and as quickly as possible, not only the anatomy of the bone but the physiology of the extremity and of the patient himself.

In treating patients with fractures our plan of action should be based on full appreciation of the details of the individual problem rather than by following blindly a certain procedure laid down for the average case. This can be illustrated by two cases which came to our own Clinic. A man came in who had fallen on his outstretched hand and the intern on duty in the accident ward suspected a Colles' fracture and sent him to the Roentgenologic Department. A little later he telephoned and was told that the man did have a Colles' fracture. The intern had been taught that the way to reduce the typical Colles' was to give an anesthetic, exert steady traction in order to disengage the fragments and then to press forward the lower fragment and adduct the wrist. This was carried out with vigor and enthusiasm and the patient splinted and sent for additional films. Later, when the intern inspected these he thought they must be the prereduction films, except that they showed a plaster splint, whereas the original ones did not. The original films showed a fracture through the distal radius with no displacement, whereas the ones taken after his efforts showed a marked forward displacement which was rather difficult to correct. The following week a similar incident happened when another eager intern converted a complicated fracture of the ankle without displacement into one which was rather difficult to get back into its original state.

The plan of action should be aimed at certain definite objectives after weighing all the factors involved. Just how these objectives are reached is of minor importance provided the plan is wisely made and carefully carried out. Splints, weights, pulleys, pins and other gadgets are means to an end and will

be used successfully only when that end is wisely and carefully planned. The objectives can be considered under five headings: (1) reduction of secondary traumata to a minimum; (2) sufficient restoration of normal form to meet the requirements of the specific case; (3) rest for the fractured part during the healing process; (4) maintenance and restoration of function of the soft parts; and (5) morale of the patient.

1. *Reduction of Secondary Traumata to a Minimum:* The ideal arrangement, if a patient is to break his leg, is to do this in a hospital where he may obtain immediately the services of a well-trained doctor who has at his disposal all of the needful accessories. Unfortunately, this rarely happens. The period of disability and the perfection of functional return is often determined more by what happens after the original injury than by the character of the accident. A great deal has been accomplished in recent years in educating the public in the proper first-aid handling of injured people. The subcommittee on transportation of the American College of Surgeons, under the chairmanship of Robert Kennedy deserves a great deal of credit for this accomplishment. The education of members of the police and fire departments in first-aid work, similar instructions given to the Boy Scouts, the many courses given under the American Red Cross have been well worth while. Over ten million Red Cross certificates for first-aid instruction have been issued since 1910, three million six hundred in 1942. The need for equipping ambulances with proper splints and the instruction of drivers in their use is being recognized more widely. The subject has been taken up by the two national associations of morticians, as they handle most of the ambulances west of the Alleghenies. Railway surgeons are doing their part. Much has been done but more is required and the gospel of "splint 'em where they lie" should be preached at every opportunity.

Two examples of first-aid treatment may be cited. A Columbia freshman football player was struck by a blocking back and fell. He said he had broken his thigh. The doctor who attends all practice periods and games came out with a Thomas splint and a stretcher, found the boy was right, applied the splint and carried him to the hospital. He was found to have a transverse fracture of the femur with almost no displacement and minimal soft-part damage. With simple treatment he was restored to normal and played three years of varsity football. A few days later another boy was brought in who had received a similar injury in a sand lot game. His own diagnosis was the same but he was helped to his feet only to collapse again so he was picked up, one man carrying his shoulders and another his middle, while the injured leg dangled. Imagine what was taking place in that thigh as the leg swung to and fro. He was laid on the side lines while someone got a car, then picked up again and put in the back seat. Getting an injured or inebriated individual through a car door onto the back seat is a complicated procedure. Arriving at the hospital a splint was applied before he was lifted out but the damage was done. The sharp end of the upper fragment had torn the overlying muscles, penetrated the fascia and overlying skin

and rested in the not too sterile football clothes. The problem of repair in this case was quite different from the other case. Protection and gentle handling in transportation and examination will do much to lessen the secondary traumata.

2. *Sufficient Restoration of Normal Form to Meet the Requirements is the Second Objective:* Reduction of existing displacement should be carried out at the earliest possible moment. When this can be done before the extravasated blood and edema have infiltrated the soft-parts and reduced their pliability, simple traction in the axis of the limb will often give astonishing results even in complicated fractures. No extensive manipulations should be attempted however until a careful examination has been made, a definite procedure planned and the necessary equipment assembled. The surgeon should study the roentgenograms himself. It is not enough to learn that a fracture exists. A number of questions should be answered. Is the bone otherwise normal or is it diseased; is there any displacement of fragments, if so, what is their present relationship; what procedures will overcome that displacement with the least additional injury; when reduced how can that reduction best be maintained; is there any injury to epiphyseal plates; are there other fractures in the area shown; what structures lie in the neighborhood such as nerves and large blood vessels whose suspected injury has not been covered by the examination or should be protected in further procedures. During our study of the roentgenograms it is wise to think of the answers to the questions which the patient or his family will ask. How long will I be in the hospital? Can I go back to my old job? When can I play golf or the violin? How much will it cost, and many others.

With a thorough understanding of the problem the plan for reduction of the existing displacements and the maintenance of that reduction can then be carried out. The object is to restore anatomic form with as little additional damage as possible. Thoughtful planning and gentle efforts are indicated. Reduction can be accomplished by manipulation, by continuous traction or by open operation, alone or in combination. The displacement of fragments usually involves a certain amount of impaction or overriding which should be overcome before any attempt is made to correct a lateral shift. This is accomplished by manual traction, initiated gently and slowly increased until the fragments have become disengaged. No attempt must be made to correct the alignment until this has been accomplished. If steady, manual traction is maintained for several minutes it is surprising how often this will be sufficient. In over 500 shoulder dislocations simple, steady traction has proved successful without the more complicated and damaging Kocher procedure in over 90 per cent of the cases.

Is exact anatomic replacement of fragments necessary? The answer frequently is no. The decision as to whether a reduction is satisfactory or not is often difficult to make. Many factors are involved. In children, especially in the first year or so, shaft fractures, whose roentgenograms would shock any jury, may often be left to nature with impunity. The main

questions are, how much will a given deformity interfere with what its owner wants or has to do; will the additional damage caused by further attempts at reduction outweigh the advantages of such attempts. A violin player needs complete supination in his left forearm. A piano player or stenographer requires complete pronation. A bricklayer or plasterer has to get his hands well above the horizontal. A mechanic or carpenter may be greatly handicapped by painful wrist rotation. One patient developed an occasional momentary pain in his thigh 23 years after I plated his femur, a trifling affair for most people. However, he was a structural iron worker then working on the 60th floor of the Empire State Building. As he said, "you only come down once in our job." An unstable ankle mortise often leads later on to an incapacitating traumatic arthritis. In epiphyseal injuries prolonged or repeated or operative attempts at correction increase the danger of growth disturbance. Sometimes a deformity needs correction although it does not affect the function of the part. Depressed fractures of the malar bone and prominent clavicles in younger females are examples.

Satisfactory reductions can be obtained best if done within a few hours of the accident. Fractures are emergencies and should not be allowed to wait until the next day or a more convenient time. Hospitals should have 24-hour and seven-day roentgenograms and emergency facilities. Reductions should be planned to meet the specific requirements of the individual case. They should be carried out as gently as possible to minimize the additional trauma. Before attempting reduction the means for maintaining that reduction should be ready at hand. An exception to the rule of immediate reduction may be indicated when a case comes late, with marked swelling. Rest, elevation, local heat for a day or so will make the reduction simpler and more efficient.

3. *Rest for the Injured Bone Hastens Healing.* The tissues of bone repair in its early stages are fragile. Each time this granulation tissue is subjected to shifts in position, fresh hemorrhage occurs and the orderly development of stronger tissue is unduly delayed. However, it would be unwise to state that rigid fixation is necessary for solid bony union. An extreme example of this occurred during the Passchendael Campaign in 1917. A British Tommy was caught in No Man's Land with a machine gun wound through his thigh and a shattered femur. He took refuge in a shell hole and lived for awhile on his own tin rations and those of several buddies who no longer needed theirs. Later, he occasionally crawled out at night to collect rations from others lying about. Finally, an advance was made and he was brought in several weeks later. Roentgenograms showed a beautiful "wipe-joint" callus, firm union and surprisingly little deformity. No splints, no traction, no physiotherapy. The same thing is illustrated by that thoroughly irrational, but surprisingly successful, method of treating humeral shafts by the so-called "hanging plaster" which does not immobilize but does provide continuous traction.

4. *The Impairment of Function of the Soft-parts is Due, in Part, to the Injuries Associated with the Original Injury and the Early Handling:* Lacer-

ation and contusion of periosteum, muscles, fascia, tendons, blood vessels, nerves, and perhaps the skin, require their own processes of repair. This is impeded by the subsequent infiltration of blood and lymph. The latter also, by increased tension, leads to circulatory impairment. Further slowing of the venous and lymphatic return comes from encircling bandages and pressure of splints. Prolonged disuse leads to atony and atrophy of muscle tissue and stiffness of joints. Since the repair of tissue, whether bone or soft-parts depends so much on circulatory efficiency, every means should be adopted to maintain this at its optimum level. Among such means are: a position of the injured part which will avoid fighting gravity; lack of constriction; local heat; gentle massage and perhaps sympathetic blocks. The most valuable aid in helping circulation, as well as in restoring the power and control of muscles and the range of motion in joints, is active motion. These movements may be guided and protected by an attendant but must be done by the patient himself. Passive movements which cause pain mean fresh injury, tearing of tissue, and do more harm than good. Occasionally, in protracted cases, where other means have failed, a single manipulation of a joint under anesthesia may be necessary.

When a satisfactory position has been obtained this can be maintained in several ways. Splints of various materials and design protect against additional injury and afford rest during the process of repair. The metal splints on the market are designed to fit the average case and rarely fit the individual. They are useful only in emergencies. The most frequently used splint is made of plaster of paris, either circular or molded. This will probably be partly superseded soon by some of the newer plastic materials which are lighter and are not opaque in roentgenograms. At present, most of them are rather slow in drying. Position can be maintained by continuous traction, usually in suspension. This is applied either by adhesive strips to the skin or by penetrating wires or pins (skeletal). Wires or pins which penetrate the bone and protrude on the outside can either be incorporated in circular plaster or attached to an outside bar, such as the Stader, Anderson, or Haynes apparatus. Position can be maintained by internal fixation using metal screws with or without plates. Each of these methods has its advantages and disadvantages. The various types of splints offer good immobilization of the bone but impair the circulation and interfere with active movements and other measures to hasten soft-part repair. Continuous traction offers less rigid fixation but avoids pressure and frequently will permit earlier active use. The combination of pins and plaster prevents shortening and rotation and is better than plaster alone. It is especially useful in oblique and comminuted fractures. Although the frequency and severity of infection of the bone and soft-parts following the use of pins and wires which protrude through the skin have proved to be less than was predicted, such complications do occur with undesirable frequency.

If it has been decided to use continuous, mechanical traction both to obtain and maintain reduction, several points should be borne in mind. The

line of pull should be in the axis of the proximal fragment. The amount of force required will depend largely on the time elapsed since the injury. With the increasing resistance due to soft-part changes, the amount of pull required increases as time goes on. Too often does the increase in force applied prove to be too little and too late. If traction alone proves unsuccessful, there is no reason why it cannot be aided by manipulation. After reduction has been accomplished, the force required to maintain the position is decreased as over-pull, with separation of fragments favors delayed or nonunion. Skeletal traction is more efficient than skin traction. The latter is to be avoided in elderly people where the wasting of subcutaneous tissue and the flabbiness of the skin make the pull less efficient and may result in tearing of the skin Traction in suspension requires hospitalization. Moreover, it requires 24-hour care by personnel trained in its use. It cannot be applied and then neglected as it needs constant care and adjustment. Unless this is available it should not be used. Open reduction and internal fixation followed by rest in suspension can provide satisfactory immobilization and unlimited treatment of soft-part damage. The risk of infection, however, is a real one.

In some fractures reduction can be obtained and maintained only by open methods. Examples are fractures of the patella or olecranon with wide separation. In this group, operation is really one of necessity. A second group includes cases where it is recognized from the nature of the injury that either immobilization by splints or the use of traction will result in considerable impairment of function or prolonged disability. If either or both of these can be lessened materially by open reduction and internal fixation, that should be the method of choice. This includes many oblique or comminuted fractures and sometimes those where the fracture lines extend into joint surfaces. Other cases present themselves where immobilization in splints or traction offers an excellent chance of completely satisfactory results, yet open reduction and internal fixation may be desirable if they can reduce materially the period of disability. The time element is often of great importance to some individuals. Open reduction and internal fixation should not be undertaken by anyone who is not qualified to carry out the necessary details. These include unusually careful technic, an adequate armamentarium and attention to the mechanical details of application. If these are neglected, results may be shockingly bad. Restoration of muscle, joint and circulatory function depend to a great extent on early use. The establishment of priorities between these two contradictory objectives adds to the fascination of fracture treatment. Methods which permit the maximum of both are desirable.

The choice of procedure is determined by many factors, the age of the patient, the details of the individual case and prognosis as to time involved and amount of eventual disability, as well as the training, facilities and aptitudes of the surgeon. Long arguments can be made for relative advantages of the dry fly, wet fly and old fashioned worm, but they all catch

trout. The method of choice in a given case is the one by which the individual surgeon can solve best the problems of that case under existing conditions.

5. *Another Objective Concerns the Morale of the Patient:* Few surgical conditions require more coöperation of the patient than fractures. All the surgeon can do is to make the conditions of repair as simple as possible. No splint, nor Balkan frame, nor plate, nor screw will make a bone unite nor will they restore to full activity the injured structures which carry out the functions of that extremity. The restoration of soft-part function is the problem where the patient can be of greatest help by his coöperation in carrying out procedures with this end in view. A patient was recently referred to me because of a completely useless hand. He applied to a hospital but being a compensation case was turned over to a member of the staff who obtained a very satisfactory reduction of a simple Colles' fracture. A splint was applied and he was told to report to the doctor's office in three weeks. At this time the splint was removed and he was given baking, massage and diathermy, the splint replaced and his forearm went back into a sling. When I saw him I asked him how often this had been repeated and he said three times a week. He had not seen the doctor since the original reduction. The treatments were carried out by the office nurse. Between visits he had continued to carry his arm in a sling giving it complete rest. This had been going on for a year and a half. His elbow, wrist, fingers showed no appreciable motion and the status of his muscles can easily be imagined. Although the compensation laws have done much to relieve the financial burden of the injured workman, the concomitant evils almost equal those of the Volstead Law. Most of these patients are not malingerers but the idea that someone else is responsible for their care has relieved them of all personal responsibility and their attitude towards their recovery is quite impersonal. Unless these patients can be made to understand that it is their own responsibility to carry out instructions, much time will be lost. The importance of gaining their confidence at the start of the treatment cannot be over-emphasized. The latter is especially true of children. You can lie to a child only once for then he will never trust you again. He, therefore, should be warned ahead of time of any painful procedures. Even adults share the same reaction. A man with a family who has adjusted his daily life to a more or less fixed income and meets with a sudden accident, needs a good deal of moral support to carry him through the period which is often so discouraging and may be disasterous. The period of rehabilitation, after the splints have been removed but before he can resume normal activities, is often greatly neglected. The work done in Army and Navy hospitals along this line has been an excellent example of what can be done. Occupational therapy should not only create diversion for a bored patient but can be made of real therapeutic value in hastening the return of flabby and awkward muscles and stiff joints.

*Compound Fractures.* In the treatment of compound fractures, all the problems of closed fractures are encountered but, in addition to these, the

additional factor of infection is introduced. The tremendous number of compound fractures handled by the armed forces in recent years and the efficient manner in which they have been treated has thrown much light on this problem. This experience has, in the main, emphasized the truth of the general principles of treatment already accepted. It has also helped to clarify some unsolved details. Among the principles emphasized are the importance of protective first aid in reducing secondary traumata and the spread of contamination; the great value of early operative removal of foreign material and devitalized tissue with control of hemorrhage—débridement; the wisdom of early reduction of deformity; the need for immobilization, as frequent change in position of bone fragments not only impairs healing but spreads infection; and infrequency of subsequent dressings.

One of the causes of shock is the absorption of toxic products resulting from traumatized tissue. An important factor in the control of shock is the early reduction of the supply of such products. It is being realized more and more that early débridement and immobilization is an essential part of shock treatment. If the patient has a palpable pulse and appreciable blood pressure, he should be taken to the operating room without delay and the usual shock procedures carried out during the operation. When this is done his condition not only improves during operation but the secondary shock after delayed operation is usually avoided.

The effect of the various forms of chemotherapy on the control of infection has been disappointing. It may be stated strongly that no form of chemotherapy offers a substitute for early, thorough surgical treatment. It is doubtful if the local use does more good than harm. General use undoubtedly decreases the danger of spreading and general sepsis.

There is still divergence of opinion regarding closure of the operative wound. Primary closure after an early, thorough, efficient operation will undoubtedly hasten repair and reduce the amount of after care necessary. Primary closure is being carried out rather extensively and is proving successful in a high percentage of cases. Its success depends on the amount and character of contamination, the time at which the operative procedure is carried out, the amount of damage to tissues, the control of hemorrhage and the avoidance of any tension in the wound. When unsuccessful, however, primary closure may give disturbing if not disasterous results. It is believed by many that the safer and wiser method is to adopt some type of secondary closure but without too much delay.

## SUMMARY

A fracture patient is a human being whose normal activities have been interrupted by an injury. This injury not only breaks a bone but causes damage to soft-parts. The object of treatment is to return that individual to a normal state as completely and as rapidly as possible. The normal state must be considered from anatomic, functional, economic and psycho-

logic standpoints. Lack of attention to soft-part damage may lead to unnecessary delay and unsatisfactory results. In planning treatment each case must be studied as an individual problem and all the factors evaluated. Success will depend more on a correct understanding of the problem and a wise plan of action than on the methods by which that plan is carried out.

# PHARYNGO-ESOPHAGEAL DIVERTICULUM: ITS MANAGEMENT AND COMPLICATIONS*

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THE SUBJECT of pharyngo-esophageal diverticulum has been discussed over the years by various authors, and the principles involved with the occurrence and with the management of this lesion have now been very well established. In spite of this fact, the number of surgeons who have had a relatively large experience with this lesion is fairly limited and it, therefore, seems to me to be of value for those who have had these experiences with this lesion to discuss them and to report the views accumulated with them.

Pharyngo-esophageal diverticula are known to originate quite consistently at the same level, that is the junction of the esophagus with the pharynx. They are known to be related to the anatomy of this point and are brought about by the relationship between the inferior constrictor muscle and the obliquely passing fibers of the cricopharyngei as they descend upon the posterior wall of the esophagus to become longitudinal.

As may be seen in the diagrammatic illustration (Fig. 1), the obliquely passing fibers of the cricopharyngei form a triangular space bounded above by the lowest fibers of the inferior constrictor and on each side by the oblique fibers of the cricopharyngei. This is known as the pharyngeal dimple and is the weak place in the posterior wall at the pharyngo-esophageal junction.

The neuromuscular coördination which brings about propulsion of food from the pharynx into the esophagus acts normally when with contraction of the constrictors the cricopharyngei relax to permit propelled food to pass into the esophagus. When there is any incoördination in this neuromuscular effort, the pressure from the constrictors and the obstruction below from the unrelaxed cricopharyngei will obviously result in a bulge at the point known as the pharyngeal dimple (see Fig 2 *a*, the first stage of the esophageal diverticulum).

As this coördination continues to produce recurring pressure upon this weak point, what was originally a bulge soon becomes a sac since the bulging pharyngeal wall is made up, in this, a false diverticulum, only of mucosa and submucosa and is covered by but a few of the remaining fibers of the cricopharyngei.

As the bulge converts itself into a sac the course of the sac as it enlarges is in the downward direction under the few enveloping fibers of the cricopharyngei, and as the sac becomes more frequently distended with food, and has for its walls only the readily stretched mucosa and submucosa, this sac

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progressively increases in size until it is in a dependent position parallel with the esophagus, with a true sac body, a true neck, and a small aperture in the midline opening into the true esophagus. This is well illustrated by Figure 2 *b*, the second stage of the development of a pulsion pharyngo-esophageal diverticulum.

With further passing of time and the accumulation of greater amounts of food within the sac and so greater distention of the sac, together with the effect of ascending and descending with swallowing, further enlargement of the sac is in the downward direction into the superior mediastinum until the size of the sac can reach good-sized proportions, illustrated as the third and final stage of the development of pharyngo-esophageal diverticulum (Figs. 2 *c* and 10).

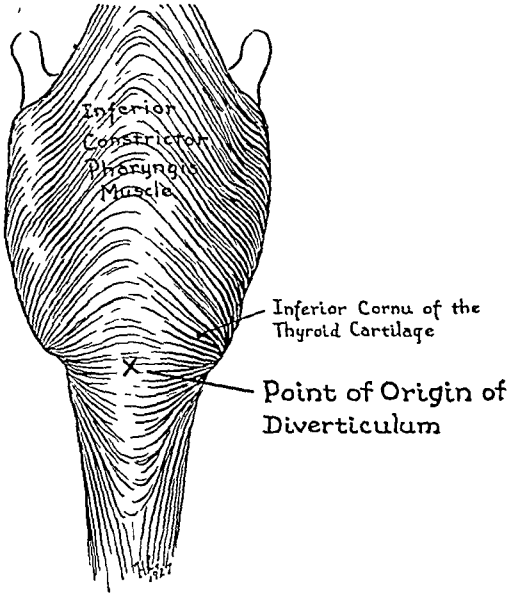



FIG. 1.—Diagrammatic illustration of anatomy at the point of origin of the diverticulum.

We have learned from this experience with these cases that each stage of this disease has with it a group of symptoms brought about by the stage of development of the diverticulum. For example, in stage 1 (Fig. 2 *a*), that is, when there is merely a bulge, there are no symptoms except those related to the occasional lodging of a dry piece of bread or cereal within this bulge, which results in recurring attempts of the patient to dislodge it by hawking. There are no other symptoms related to this stage of the diverticulum, and because there is no neck to the sac and it is only a bulge, operation is neither necessary nor advisable.

The symptoms related to the second stage (Fig. 2 *b*) are merely those associated with the presence of a sac and to the fact that this sac constantly has contents made up of food mixed with air and mucus. It is to be remembered that an esophageal diverticulum is a sac placed in front of the prevertebral fascia and behind the pretracheal fascia, that it ascends and descends with swallowing, and that its contents are variable in amount so that the degree of distention within the sac is variable. It is to be recalled also that the sac rests posteriorly upon a rigid structure, the vertebral bodies, and is covered in front by the sternomastoid, omohyoid, sternothyroid, and the overlying thyroid gland. With this anatomy in mind, one can realize how, with changes in position of the neck and chin, there are changes in pressure on the fluid and air filled sac by these overlying structures against the nonresistant posterior boundary. This produces unpredictable expulsion of food and mucus which can come up into the mouth anytime during the day or night. In addition to

this, as a result of pressure upon the sac as it ascends and descends with swallowing, the mixture of air with food and mucus can produce gurgling noises which are audible to friends of the patient who eat at the table with him and which at times occasion embarrassment for the patient, since inquiries are frequently made as to the causes of obvious noises in the patient's throat as he swallows.

Since with change in position the contents of the sac can be unexpectedly expelled into the pharynx, it is also obvious that changes in position at night

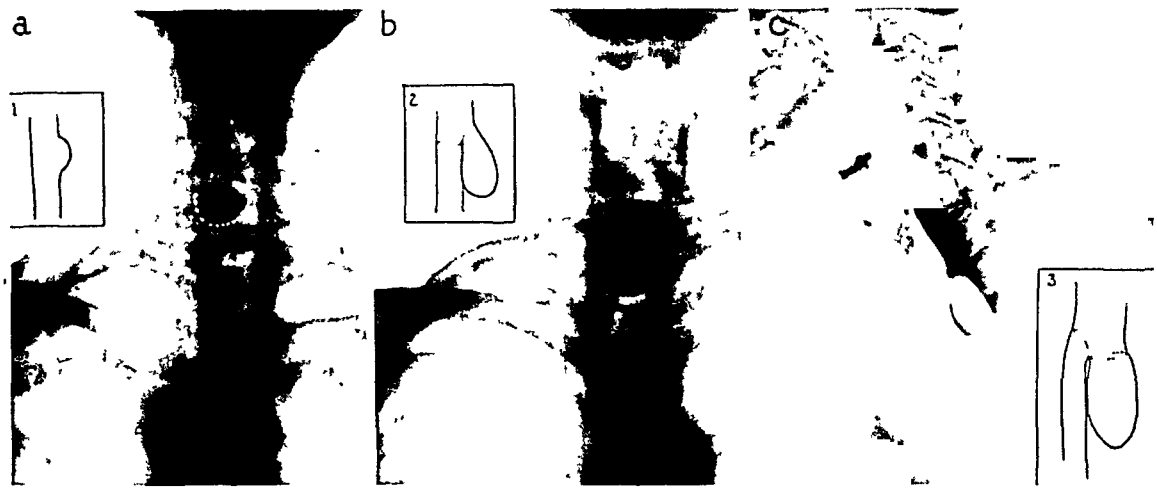



FIG. 2.—*a*, Note that this is the first stage of esophageal diverticulum, shown diagrammatically by the bulge in insert 1 and by the roentgenogram. Note absence of any sac.

*b*, In this illustration is shown the second stage of esophageal diverticulum with a true sac. Note that the opening into the esophagus at this stage is longitudinal while the opening into the sac is lateral.

*c*, This illustration graphically demonstrates why obstructive symptoms occur at the third stage of development of a diverticulum. Note that the direct opening is now into the sac of the esophagus, its opening being transverse, while the opening into the true esophagus is now lateral (see insert 3). The thin stream of barium can be seen overflowing from the sac through the laterally placed opening into the true esophagus.

with the head and neck at various angles on the pillow, can bring about unpredictable expulsion of the sac contents into the pharynx with occasional inspissation of the contents, strangulation, and the danger of lung abscess.

Many of these patients have come to us seeking operation because of some of these above stated features, because they are so embarrassed with the noise they make in their throat when swallowing, because they have so frequently been awakened at night by the expulsion of food that it interferes with their sleep, and because in four cases the inspissation of food has produced lung abscesses.

All of the symptoms associated with the second stage of the development of this condition just spoken of can be associated with the third stage (Fig. 2 *c*) of the development of pharyngo-esophageal diverticulum, that is, the stage with the large sac. This stage is, however, distinguished by the fact that it is only at this stage that obstructive symptoms occur. I wish particularly to discuss the cause of obstruction at this stage in order that anyone dealing with a patient with a large pharyngo-esophageal diverticulum of the third

stage will understand its cause and its management, particularly as relates to attempting to pass an esophagoscope or attempting to introduce a feeding tube preoperatively before the sac has been freed and completely dissected and especially because of the danger of attempting to pass a bougie at this stage.

When we first began to operate upon patients with large esophageal diverticula who had obstruction, it was my impression that the obstruction was

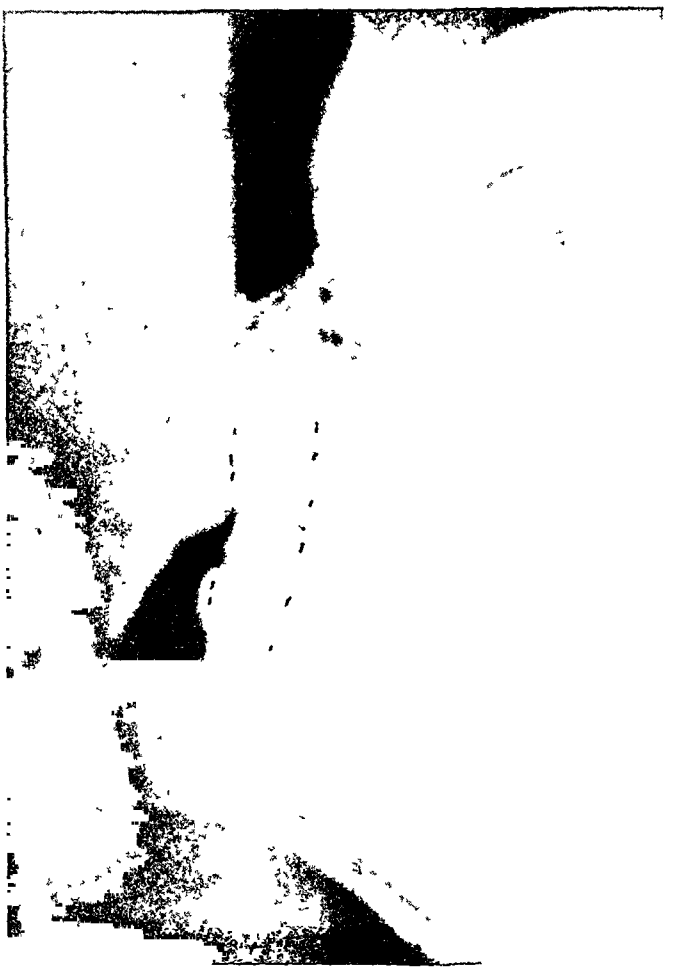


FIG. 3.—A further excellent illustration of stage 2. Note the well formed sac with a neck, the lateral opening and the true esophagus outlined by dots.

probably due to the pressure of the very large, filled sac against the lateral esophagus. It was some time before I realized that this was not the case.

In stage two when the sac is first developed and is of only moderate size, it will be seen, as illustrated in Figures 2 *b* and 3, that the opening into the sac is on the lateral wall of the esophagus and that the opening into the true esophagus is in the normal transverse position. However, as this sac enlarges, and as a result of its enlargement together with the weight of its contents, descends into the mediastinum it drags the lateral wall of the esophagus down-

ward with it and, as shown in Figure 2 *c*, converts the opening into the diverticulum sac into a semitransverse one and the opening into the true esophagus into a semilateral one (Fig. 2 *c*, insert 3). As may be visualized from the diagrammatic illustration (Fig. 2 *c*, insert 3), as the sac becomes larger, more distended and its contents heavier, and as it descends farther into the mediastinum, this downward traction converts the true opening into the esophagus



FIG. 4.—Note loss of irregularity in one-fourth of the circumference of the otherwise discretely outlined sac in which malignancy was present.

not only into a semilateral one but by the traction tends to pull the two lips of the opening into the true esophagus together and convert it not into an aperture but into a slit.

I am anxious to present this viewpoint in order that in this stage attempts will not be made to pass an esophagoscope or to introduce a tube, because either the tube or the esophagoscope will pass into the sac, cannot be manipulated in the advanced cases into the lateral opening and if any pressure is persisted in, will result in perforation of the sac, as has occurred before coming to us in a few of the cases which we have seen and has been followed by serious mediastinitis. Perforation had occurred in four of the patients coming to us,

necessitating gastrostomy, drainage of the fascia planes of the neck, drainage of the mediastinum, and in one case the drainage of a mediastinal abscess by posterior mediastinotomy elsewhere before the patient came here for repair of the diverticulum.

### COMPLICATIONS OF DIVERTICULUM NOT ASSOCIATED WITH SURGERY

The complications, other than those of obstruction, of esophageal diverticulum of the pulsion type not associated with the operative procedure are largely limited to the development of carcinoma in the walls of the sac of the diverticulum.



FIG. 5

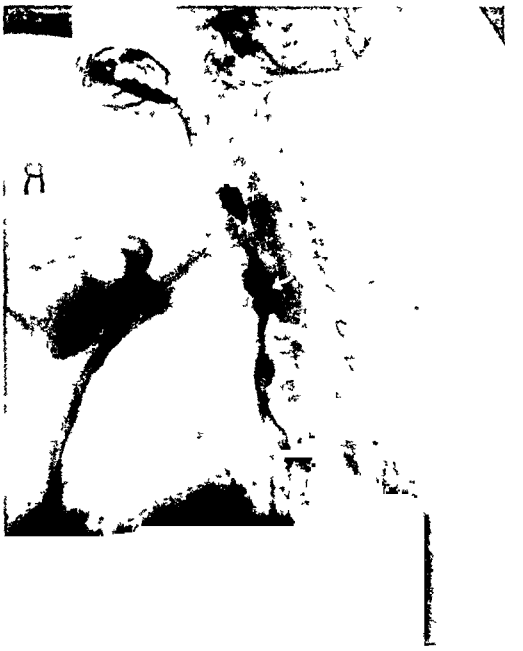


FIG. 6

FIG. 5.—This patient, whose roentgenogram is shown here, was sent to the Clinic for operation of esophageal diverticulum. Note, as shown by arrows, the escape of fluid from the lowest point. This was a high esophageal web.

FIG 6.—The same patient as in Figure 5, shown laterally. Note the absence of the spill-over stream, which characterizes a true esophageal diverticulum, and the emergence of the barium from the lowest point. This patient was completely relieved by dilatation.

The indications of the occurrence of a possible malignancy within the sac are particularly related to the appearance of blood in the mucus expelled from the sac or a suspicion of malignancy created by the roentgenologic appearance when the outline of the sac edges are irregular. They should be, in cases uninvolved with malignancy, sharp and clear. In those patients, as shown in Figure 4, with malignancy involving the diverticulum, this outline is no longer sharp and clear but is irregular in character.

### NONOPERATIVE TREATMENT

The nonoperative treatment of pulsion esophageal diverticulum consists solely of dilatation. It is of very doubtful value in stage one (Fig. 2 *a*), it is

impossible in the cases with a marked degree of obstruction in stage three (Fig. 2 *c*), and is applicable only, from a practical point of view, in stage two (Fig. 2 *b*), in which the opening into the true esophagus is completely transverse and permits the dilator or bougie to pass readily into the longitudinal esophagus and permit dilatation of the portion of the esophagus from which the diverticulum springs.

During the period when an esophageal diverticulum of this type is at the second stage, dilatation produces considerable relief by lessening obstructive symptoms. It does not, however, materially delay the increase in size of the sac, nor does it do away with the unpredictable occurrence of regurgitation, the comment-causing noises which at times occur during eating or the dangers of the inspissation of food and mucus regurgitating from the sac during the night.

It is important, I believe, to call attention to the necessity of doing the dilatations, if they are to be done, at this period, on a string previously swallowed to insure that the bougie does not pass blindly into the sac because if it does, any pressure upon it can readily perforate it.

## DIFFERENTIAL DIAGNOSIS ROENTGENOLOGICALLY OF PULSION ESOPHAGEAL DIVERTICULUM

So distinctive is the roentgenogram of pulsion esophageal diverticulum that one would hardly think it possible to be mistaken as to its diagnosis. I wish particularly to warn that such is not the case. In certain cases with a high web in the esophagus (Figs. 5 and 6), in certain cases roentgen-rayed postoperatively sometime after removal of an esophageal diverticulum (Fig. 7) and in certain cases with high stricturing of the esophagus, there will be a dilatation of the esophagus above the web, scar of the previous operation or stricture, which by roentgen ray will by its spherical character lead anyone who has not had considerable experience with these into assuming that what is really only local dilatation is a true esophageal diverticulum (Fig. 8).

As will be seen in Figure 9, the distinguishing feature of a true diverticulum is the demonstration of its body, neck and the spill over of the thin barium mixture after the sac is filled into the true esophagus, which can be shown, when viewed laterally (Fig. 9), in most of the cases as a thin line running from its neck down behind the sac. In those cases in which there is only a dilatation, if this thin line be seen, it will emerge from the bottom, most dependent portion of the sac where the narrowed point is (Figs. 5, 6, 7 and 8), and on lateral view will never be seen behind the diverticulum, and representing the spill-over from the highest point of the sac.

Unless a definite body, neck and aperture into the esophagus of a suspected pulsion esophageal diverticulum (Fig. 9) can be demonstrated in the roentgenogram the patient brings with him, these sacs should be visualized under the fluoroscope, and another roentgenogram taken, particularly in the lateral position, to demonstrate that the lesion is a true diverticulum and not esophageal narrowing—the spherical dilatation as shown in Figure 8.

BEST TIME FOR OPERATION

As already stated, operation should not be done in the first stage (Fig. 2 *a*). Since there is no neck at this time, there are no symptoms of significance and the sac has not as yet so developed that it can be amputated. The most desirable time at which to operate upon a patient with an esophageal diverticulum is in the early portion of stage two (Fig. 2 *b*). At this stage the sac is small, there are no inflammatory adhesions, it has a good neck, the aperture into the esoph-



FIG 7.—This is the dilatation above the scarring following the removal of an esophageal diverticulum Notice the apparent appearance of a neck at the arrow but that the barium emerges from the lowest point of what appears to be the sac. This is a dilatation above the scarred esophagus.

agus is small, it is possible to dissect the sac with no great difficulty and the patient has had no obstructive symptoms to in any way seriously affect his health. In addition, at this stage the sac can be readily buried in the wound between the first and second stage of the operation and when the wound is reopened, with its small neck, ligation of the neck flush with the longitudinal esophagus can be readily accomplished, with amputation of the remaining

portion of the sac easily, quickly and with less likelihood of recurrence than exists in those cases in which the diverticulum has gone on to a large sac and with a large aperture between the sac and the true longitudinal esophagus.

If operation is carried out at the third stage when the sac is large and located within the mediastinum, the sac will, as a result of inflammatory reac-



FIG. 8.—Based upon this roentgenogram, without a lateral view, this patient was operated upon for an esophageal diverticulum which proved to be only a dilatation. Had a lateral view been taken, it would have been demonstrated that there was no spill-over, as shown in Figure 9, which is a true esophageal diverticulum.

tion within the sac, occasionally be adherent in the mediastinum to the posterior aspect of the pleura. Its removal will leave a large mediastinal cavity, the sac will be so large that it will require implantation not in the wound but upon the neck (Fig. 10) and the opening into the true esophagus will be so large

that a ligature will not be as satisfactory as will suture of the neck of the diverticulum. As a result, a suture which must be done on the posterior wall to secure approximation can never be as satisfactory as one would desire as relates to accurate closure and certainty that leakages will not occur.

With a Levine tube introduced into the stomach through the nose and feeding through this tube maintained for seven days postoperatively, in most of the cases there will be first intention healing, but because of the inaccuracy of the suture the large apertures into the true esophagus when the sac is large in third stage cases, there will be occasional cases in this group in which leakages occur. Having been done, as these cases have, in two stages, there will be no danger of mediastinitis or fascial plane cellulitis, but there will be in those rare cases of leakage the undesirable complication of food and fluid discharge through the wound until granulation and closure have occurred. It is for this reason that I wish to strongly urge that patients with esophageal diverticula be persuaded if possible to have their diverticula operated upon in the second stage and before they have reached the development of the third stage.



FIG 9.—This is a true esophageal diverticulum, the lateral view showing the spill-over, the neck and that the true longitudinal esophagus is at the top of the sac where the thin stream of barium appears, and not at the bottom as occurs with simple dilatation.

### ANESTHESIA

In the beginning of our experience, because we were never quite sure about the diverticulum and wished to have the patient able to swallow so that we could locate the diverticulum as it ascended and descended, these operations were done with procaine cervical block. This has for some time now been entirely abandoned in favor of general anesthesia, largely with ethylene and with an intratracheal tube. This is much more satisfactory to the patient and to the surgeon. As a result of our increasing experience with these cases we have no difficulty in finding the sac, and local anesthesia in the form of cervical block is a trying ordeal to the patient, only partly effectual in some cases and far from satisfactory even in expert hands in others. In addition to that, the position in which these patients must be, with their chins turned to one side, with their neck extended and their chest thrown forward, is an extremely uncomfortable one for the patient under local anesthesia to endure

during the period when this painstaking, accurate and in certain cases time-consuming procedure is carried out.

### OPERATIVE PROCEDURE

The incision in esophageal diverticulum is of the utmost importance. I have never been in favor of doing this operation, which can be technically difficult in a field filled with complicated anatomy, with any limitation as to the adequateness of the exposure. For that reason I have never been interested in incisions of the goiter type made because of their superior appearance, as compared with the longitudinal incisions. We have always employed long



FIG 10.—This illustrates how in an esophageal diverticulum with a very large sac it is necessary to implant the sac on the neck One can realize in a sac that has reached this proportion how large the opening into the true esophagus will be and how undesirable it would be to attempt to ligate such a mass of esophageal tissue.

longitudinal incisions parallel to the anterior border of the left sternomastoid muscle. This provides what is so important in this condition, adequate exposure, good visualization of the anatomy, accurate control of bleeding so that the field can be kept dry, and anatomic relations at all times established. The need for these requirements, in my opinion, and the hazards of this procedure, particularly in difficult cases, by far exceed the importance of the appearance of the scar.

These incisions need to be carried high, up to and above the level of the point where the superior thyroid artery passes as the first branch of the external carotid to the upper pole of the thyroid gland, and low to the point

where the sternomastoid is inserted into the sternum in order that the inferior thyroid artery beneath which the sac always passes, may be visualized and in order that the lower portions of the deep sac in the third stage of this condition may be clearly visualized.

*Operative Steps.*—The first step of the procedure for the removal of esophageal diverticulum after the longitudinal incision has been made and the platysma cut, is the separation of the anterior edge of the sternomastoid muscle throughout the entire extent of the incision from the underlying prethyroid muscles. If this is done and the sternomastoid is pulled back, the anterior belly of the omohyoid muscle immediately comes into view. This is followed up to its point of insertion, a clamp is applied at its tendinous portion and the higher portion of the anterior belly of this muscle is freed, ligated at its insertion and at the tendinous portion, and removed. This immediately makes visible the internal jugular vein, the outer border of the sternohyoid muscle and the underlying thyroid gland with the superior thyroid artery passing into the upper pole, and the upper, middle and inferior thyroid veins passing from the thyroid gland to the internal jugular vein. These thyroid veins are doubly ligated and severed in order that a double blunt retractor may be placed under the outer edge of the thyroid gland and that structure so elevated that the inferior thyroid artery, beneath which the sac of the diverticulum passes, comes plainly into view. With the common carotid artery and the internal jugular vein retracted outward, the gland retracted inward (Fig. 11 *a*), the inferior thyroid artery comes into view. This is doubly ligated between clamps and beneath it will be found the sac of the diverticulum even in those cases with the smallest type of sac (Fig. 11 *b*). In large sacs this will make possible the dissection of the sac and the delivery of the sac out of the mediastinum. Without severing the inferior thyroid artery, this approach and dissection is impossible.

As soon as the diverticulum sac is identified it is grasped with Babcock forceps at its tip and the separation of the inner wall of the sac from the longitudinal esophagus immediately undertaken. In large sacs extending into the mediastinum the sac is gradually lifted out of the esophagus, placing Babcock forceps on the delivered portion progressively as it is pulled out of the mediastinum.

It is frequently possible to introduce one's finger along the outer edge of the sac and gently elevate the sac out of the mediastinum if it is not adherent. It can then be pulled away from the longitudinal esophagus so that the dissection between the inner wall of the sac and the lateral wall of the true esophagus can be carried accurately up to the neck of the sac (Fig. 11 *b*).

It is to be recalled that in all of these sacs there is a varying degree of investment of the sac by the fibers of the longitudinal esophageal muscle, spreading over it as a thin web of muscular tissue. It is of the utmost importance that the sac of the diverticulum be so dissected from its dependent position and that the acute angle made at its neck by the inner wall of the sac and the left wall of the true esophagus is completely freed (Fig. 11 *b*).

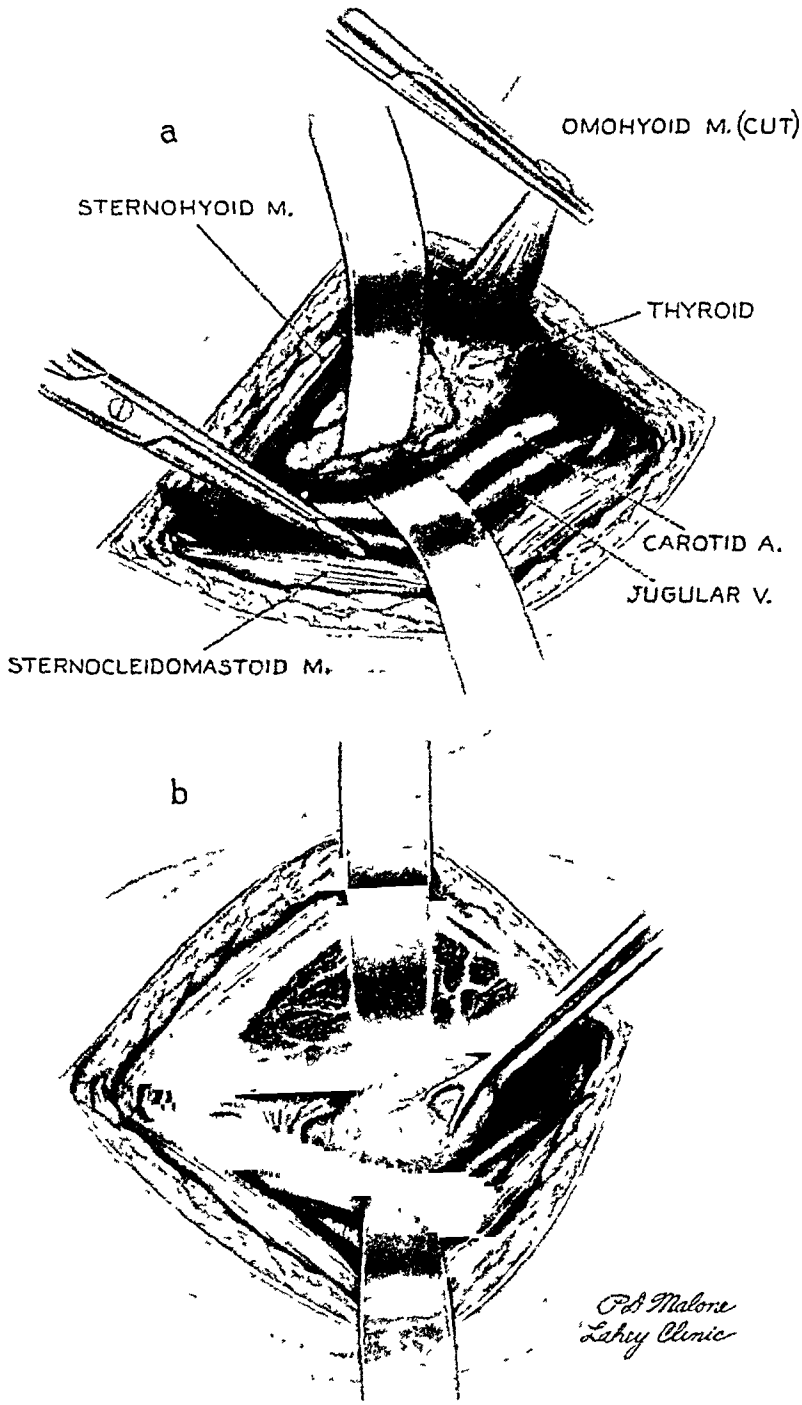



FIG. 11.—*a*, Note in this illustration that the omohyoid has been severed at its tendinous portion and the point of insertion is not shown in this illustration as clamped. The anterior belly is, however, to be removed. Note the retractor pulling the thyroid inward and the retractor ready to pull the common carotid and the internal jugular outward.

*b*, Note in this illustration the inward retraction toward the midline and the outward retraction of the large vessels. The diverticulum sac is completely dissected from its attachment to the longitudinal esophagus and pulled upward. Note the remaining circular fibers of the cricopharyngei or inferior constrictor about the lower angle of the sac neck. These are to be severed.

As shown in Figure 11 *a*, in order to be sure that one has completely accomplished the dissection of the neck of the sac, this dissection must be carried completely around the neck of the sac until the pale white membrane of the submucosa is shown. It is only when this structure can be demonstrated around the entire neck of the sac that one can be sure that all of the muscle fibers enveloping the sac have been removed and that the acute angle at the neck of the sac has been completely dissected (Fig. 12 *a*).

There will be a tendency of everyone who has not had considerable experience with this dissection to stop short of complete dissection of the lower angle of the neck of the diverticulum sac. This will be true because there will be a constant fear that too extensive dissection at this point can result in perforation into the sac at its neck. It is for this reason that I have always employed the Berens-Beebe loupe to magnify the field at this time and make certain that the dissection here is not carried beyond the safe point of the wrong side of the pale white submucosa and a perforation produced.

If the angle, as shown in Figure 12 *b*, is not completely freed, one can see that this will produce a shelf or ledge which will catch food, throw it out into the incomplete sac which will remain after suture or ligature of the necessarily incompletely removed sac, which will exist when this mistake is made. As a result of this pressure, there will be present all of the factors for the formation of a new sac.

There is nothing in my opinion which is of greater importance in preventing the recurrence of an esophageal diverticulum than the complete dissection of the lower angle of the neck of the sac made by one lateral wall of the longitudinal esophagus and the corresponding lateral wall of the sac of the diverticulum (Fig. 12 *a* and *b*).

Since esophageal diverticulum actually arises posteriorly from the midline of the esophagus, it is obvious that the dissection of the sac on the left side will not be difficult because it can be so satisfactorily visualized, but the dissection of the envelopment of the sac by the longitudinal muscle fibers on the right side, and the delivery of the sac to the left will at times be extremely difficult. This will be due to the fact that the investment of the sac on the right side cannot be visualized. It will be necessary by rotating the sac laterally to the left to gradually remove the investing fibers on the right side, and it is at this point that there is the greatest danger of unwittingly making a hole in the neck of the sac on the right side (Fig. 13).

So great is the danger of perforating the sac in freeing it from its muscular investment on the blind right side that it is my opinion that if there is any difficulty whatever in doing it or any uncertainty about the safety of doing it, the sac should be delivered as far as possible and the freeing of the right side of its neck from musculature investment delayed until the second stage when it can be done with just as great ease and with the added safety of the fascia planes and mediastinum being so sealed-off should a perforation be made in the neck at this point that it will not result in a mediastinitis and possible fatality.

With the sac completely dissected, if it is large, it is implanted in the

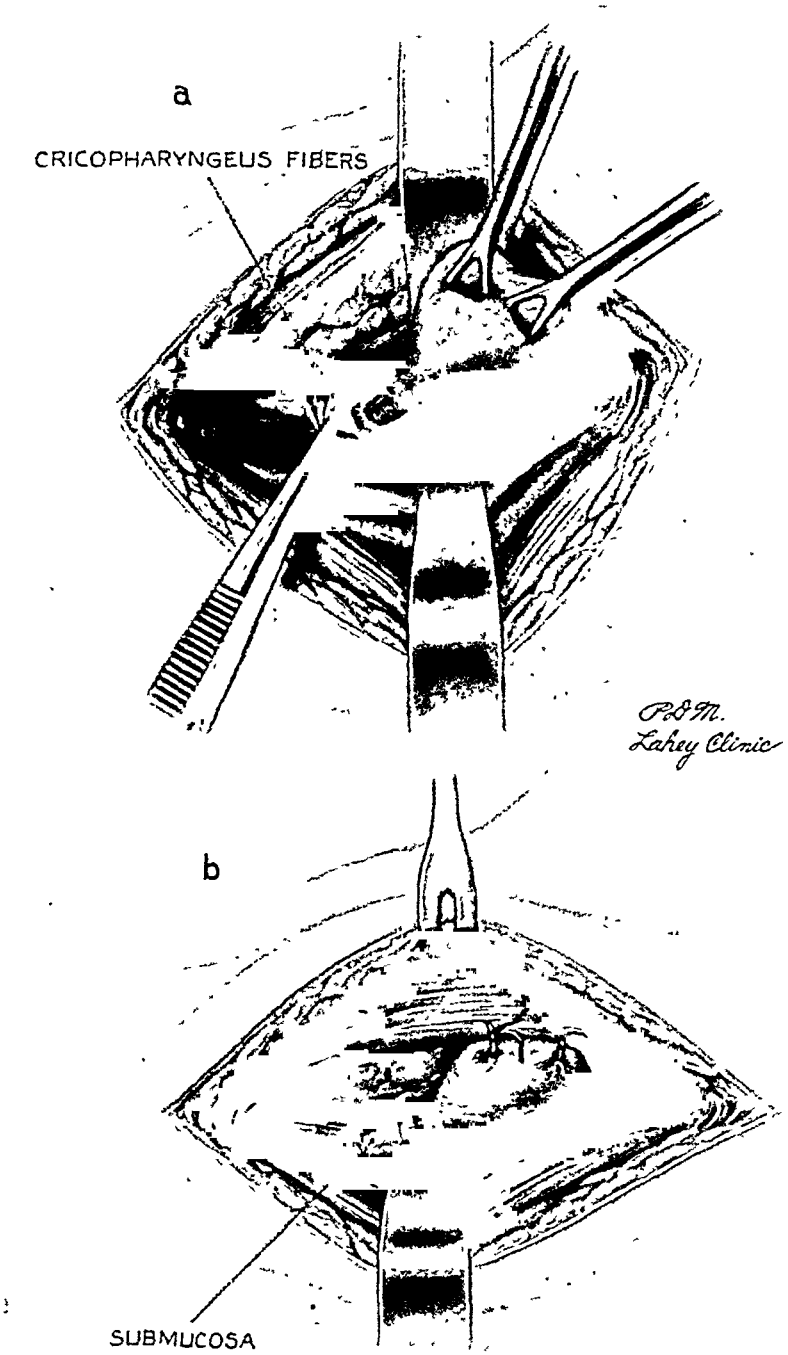



FIG. 12.—*a*, Note in this sac the complete dissection of the neck, with the pale white surface of the submucosa. Note the removal of the sling fibers about the neck of the sac at the angle. The sac has been completely dissected from its attachment to the longitudinal esophagus so that it actually hangs by its neck.

*b*, Note again the completely dissected neck with its pale white submucosa and that the sac has now been approximated to the prethyroid muscle.

This illustration gives the impression that the stitches have passed through the sac. They have been passed through only the adventitia about the sac but care is taken to see that the needle does not penetrate the sac. This makes it possible to bury the small sac within the wound and to find it easily at the second stage of the operation.

wound and on the neck for seven or eight days (Fig. 10). If it is small, the tip of the sac is sutured high up to the very outer edge of the sternohyoid muscle, care being taken to tie the silk suture about some of the adventitious tissue over the sac and not to put a needle through the wall of the sac (Fig. 12 *b*). If a needle is put through the wall of the sac to sew it to the prethyroid muscle, this will result in its pulling away with swallowing, in leakage, and will result in undesirable contamination and infection of the wound.

As shown in previous descriptions of this procedure, two black silk stitches (Fig. 12 *b*) are used to suture the sac to the uppermost edge of the sternohyoid muscles, leaving the ends long, by means of which the point of fixation of the sac can be readily demonstrated at the second stage of operation.

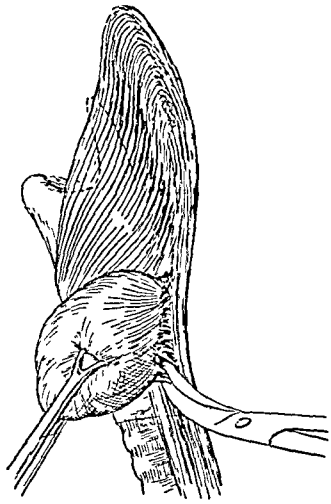


FIG. 13.—This diagrammatic illustration is included without the surrounding anatomy to demonstrate how the musculature enveloping the sac on the right side must be freed in order that the submucosa completely around the neck of the sac can be demonstrated.

Since this dissection of the right side must be made through a left incision, the difficulty of exposing this region is obvious.

If the mediastinum has been widely opened, a good sized pack is introduced into it and carried up along the edge of the longitudinal esophagus to the level of the neck of the diverticulum. This pack is left in place for four days at the end of which time it is removed entirely. The second stage of the operation is carried out seven to eight days later.

It is readily possible with a large diverticulum sac to pull it so far out upon the wound that there will be such angulation of the esophagus that the patient will not be able to swallow between the first and second stages. Before implanting a large sac in the wound and on the skin one must be careful to see that the longitudinal esophagus is in the midline and not disturbed and distorted in its course.

*Second Stage.*—The second stage of this operative procedure can be undertaken at any time in from seven to twelve days after the first stage. We have done these second-stage procedures at various intervals of time, and it is my opinion that the operation will be most satisfactory when it is done on approximately the seventh, eighth or ninth day after the first stage.

If one does not undertake the second-stage operation until a later day than this, the wound will be firmly united, quite difficult to separate and the difficulty of establishing cleavage planes will be greater than if the operation is undertaken on the eighth day.

Even though the drain has been removed on the fourth day, if the second stage of the operation is undertaken on the eighth day there will still be a drainage canal along which a finger can be inserted as the wound is opened.

This is a desirable line of cleavage to establish as it permits separation of the granulation-covered internal jugular vein and common carotid artery from the prethyroid muscles, thyroid and esophagus so that they can be separated in opposite directions and the region of the esophagus exposed.

At this point the black silk sutures anchoring the sac to the prethyroid muscle are found indicating the location of the implanted tip of the sac. The sac can readily be picked up with tacking forceps, severed from the point where it is sutured to the prethyroid muscles and its neck easily wiped out with gauze. When the neck has been well freed at the first operation, its relation

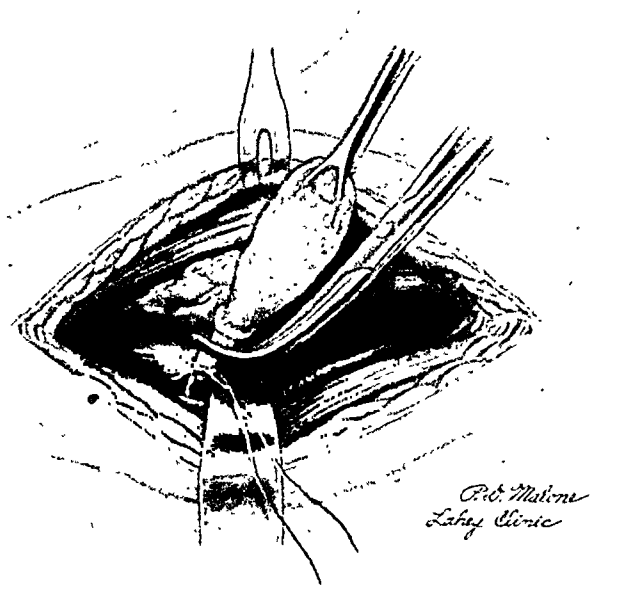



FIG. 14.—This illustration represents the method of ligating the sac at the second-stage procedure when all the fascial planes have been walled-off. One ligature is shown about the sac already tied, the second ligature is about the sac but not yet tied. Note the clamp applied distally to avoid spilling of the infected contents of the sac. Note again that the pale white submucosa, demonstrating how completely the neck of the sac has been dissected, is shown.

to the true esophagus can easily be established at the second operation, and in those patients with a small sac and a narrow neck, an accurate ligature of o chromic catgut can be passed around the neck flush with the esophagus. The neck is doubly ligated, the neck of the sac distal to the ligature clamped and the neck itself severed (Fig. 14). A small amount of sodium sulfathiazole is placed over the ligated neck of the sac, a cigarette drain laid over this, and the wound reclosed.

In the large sacs implanted in the wound, the neck can be readily reopened along the neck of the sac as it emerges onto the skin where it is placed.

At the second stage of the operation it is wise and of no disadvantage to reopen the wound completely throughout its full extent since it heals readily

when reclosed. This gives adequate exposure of the anatomic structures, permits free mobilization of the sac and makes much easier the ligature or suture of the neck of the sac. Suture of the neck of the sac at best is difficult since it must be done behind the esophagus and where the esophagus joins the pharynx.

As already stated, in small sacs, a double ligature of the neck of the sac and cutting away the sac is an extremely satisfactory way of handling them, but in either large or small sacs one should first introduce a Levine tube

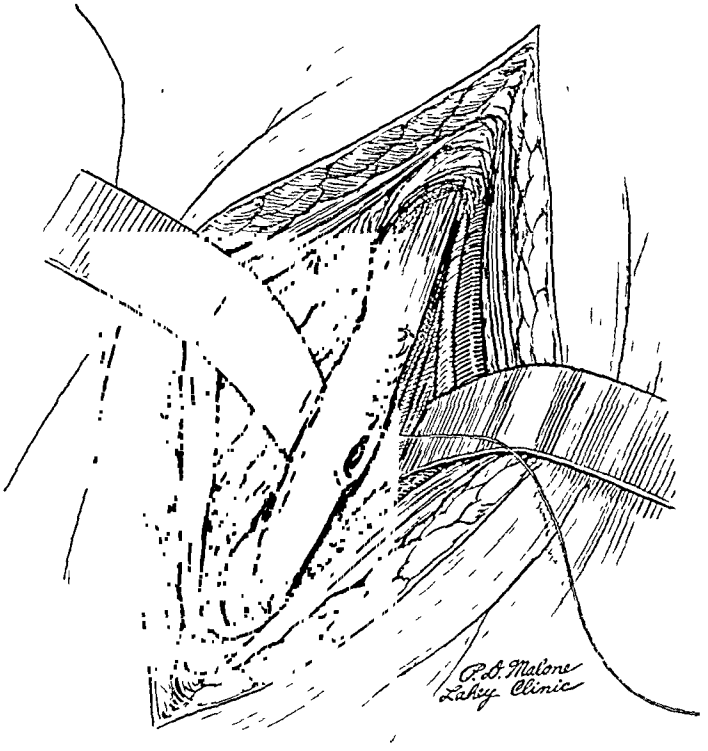



FIG. 15.—This illustration shows the method of suturing the opening into the esophagus in large diverticula with large openings into the esophagus. These openings are so large that ligature of such a large mass of tissue is less satisfactory than is suture. I would like to say for the benefit of anyone doing this suture that such are the difficulties of doing it that it is often a far from accurate suture line but, with an indwelling tube, rarely leaks.

through the nose into the stomach at the time of the second-stage operation. If there is any difficulty in passing it into the esophagus, this can be delayed until the neck of the sac is exposed at the second stage, at which time the operator can, as the anesthetist passes the tube down into the pharynx, guide the tip of the tube into the longitudinal esophagus. This is important since with either suture or ligature of the neck of the sac, all feedings should be maintained for seven days through the indwelling nasal Levine tube in order to give the closed esophagus an opportunity to heal by first intention.

I wish to warn particularly of the difficulty of suturing the neck of the sac in diverticula with large sacs when the opening into the true esophagus is

frequently of considerable size. Since the right side of the neck of the diverticulum sac cannot be visualized, one must be careful lest in his enthusiasm to get rid of the entire sac that part of the right lateral wall of the esophagus is not so pulled over and sutured to the left side that there is narrowing of the esophagus. I have personally done this in one case, necessitating reoperation and a plastic upon the narrowed esophagus. Again, a drain is inserted into the mediastinum and along the edge of the esophagus, which remains for four days, at the end of which time it is completely removed.

### COMPARISON OF THE TWO-STAGE WITH THE ONE-STAGE PROCEDURE

There have been but two deaths in this group of 209 cases, all of which have been done by the two-stage method. One was due to an error in judgment in operating on a man 84 years of age who had had complete obstruction for some time and who died of uremia four days after the first-stage operation and with no difficulty relating to the operation upon the diverticulum.

The second fatality was a technical error in a patient upon whom I made an opening on the blind right side of the sac without being aware of it until three or four days after operation when food and saliva escaped from the wound. This was a technical error, and this patient died of mediastinitis in spite of gastrostomy and posterior mediastinotomy.

The decision to remove a pulsion diverticulum by one or two stages must be largely a matter of personal choice; the mortality of reported series done by both methods is approximately the same. The period of stay in the hospital, now that we have been successful in a series of over 60 cases in successfully closing the opening into the longitudinal esophagus at the second stage and obtaining first intention healing without leakage, is about the same, approximately two weeks. The incidence of recurrence by both methods will be about the same since it depends largely upon how well and how completely the sac has been dissected and because by either method their exist no muscular structures of any real value which can be sutured over the ligated or sutured sac neck to reinforce it.

My own adherence to the two-stage plan of operation is due to the fact that the only two deaths which have occurred in 209 cases have been my fault and not the fault of the operation and because at the second stage of the two-stage operation, when the mediastinum and the fascial planes of the neck are sealed off, should there be leakage, as will occasionally occur with either the one-stage or the two-stage procedure, I do not have to worry about either mediastinitis or fascial plane infection in the neck. This is particularly true when the closure of the remaining opening into the esophagus can be just as satisfactorily done at the second step of the second-stage procedure as it can at the time of exposure and ligature or suture in the one-stage operation.

With no purpose of disparagement of the one-stage operation, with no attempt to persuade those who employ it away from its use, with perhaps an unnecessary sense of caution concerning the possibility of the occurrence of mediastinitis when leakage with the one-stage operation occasionally occurs,

as it does, but with a gratifying certainty that when leakage does occur after the second-stage procedure of the two-stage operation, as it occasionally does, mediastinitis will not occur, I would, I believe, should I ever have to have this operation done on me, accept the relatively simple second-stage procedure. I would consider it a small price to pay for the peace of mind which goes with it regarding absence of leakage dangers, for other than this and perhaps the three to four extra days in the hospital, there is nothing different in the effectiveness of either plan of operation.

# DIVERTICULA OF THE LOWER THORACIC ESOPHAGUS*

## REPORT OF SIX, FOUR OF WHICH WERE OPERATED UPON

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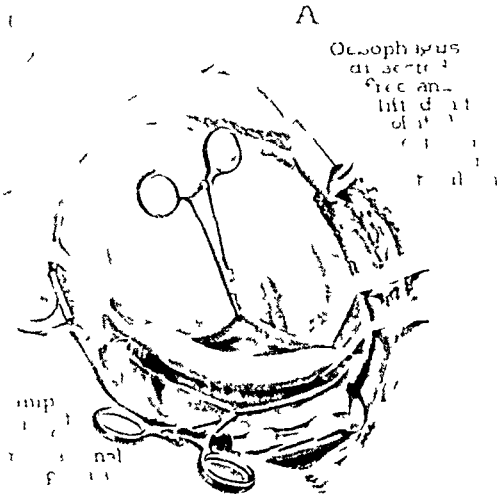
THE AVAILABLE LITERATURE would suggest that diverticula of any portion of the thoracic esophagus are uncommon. In 1928, Smith[2] was able to collect from the literature, between 1919 and 1926, inclusive, four diverticula of the upper third, six of the middle third and 16 of the lower third. He reported nine cases, six single and three multiple, only two of which were limited to the lower third, and stated that Dessacker found reports of 21 diverticula of the epiphrenic variety which, with his own and those of Carman and Hurst, made a total of 26. Vinson[3] collected 42 cases of diverticula of various portions of the thoracic esophagus from the records of the Mayo Clinic up to 1934. Only 18 of these patients were thought to have symptoms which could be related definitely to the diverticula and in none of these was the disability considered great enough to warrant operation. Barrett,[1] in 1934, was able to collect from the literature a total of 115 cases and to report one of his own which he operated upon, with a satisfactory result.

While it is probably true that these reports do not really represent the frequency of the disease and that with improvements in roentgenologic methods of examination of the esophagus the condition is likely to be recognized more frequently, reports of what may be called giant diverticula remain of interest.

Diverticula of the thoracic esophagus are described as of the traction or pulsion variety. The former are characteristically of a more or less conical shape and result from fixation of a point on the outer wall of the esophagus to an adjacent inflammatory area most often a tuberculous lymph node. Because they have wide-open mouths food is unlikely to stick in them and they do not produce symptoms except in the rare instances in which perforation occurs. The pulsion form is said to result from herniation of the mucous membrane through the muscular wall and to be enclosed, therefore, by mucosa, submucosa and fibrous tissue only. The diverticula removed in this series had rather thick walls formed of squamous epithelium, submucosa, muscularis mucosa and a layer of fibrous tissue. The muscle in Case 1 was of considerable thickness but apparently represented muscularis mucosa only. The muscle in the other cases was patchy in distribution and rather scanty. In all, there was a fairly marked infiltration of inflammatory cells in the submucosal area. Their etiology is obscure. Some appear to be associated

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

FIG. 1



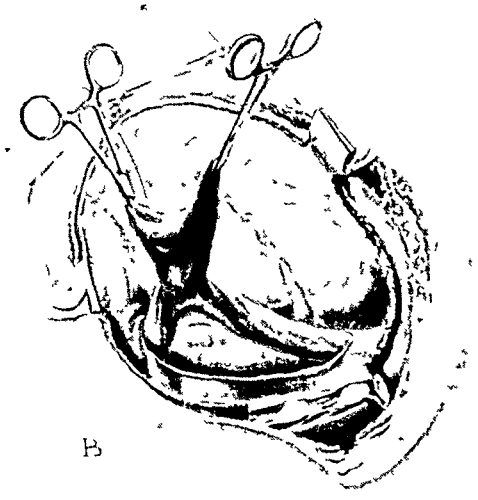




FIG 2

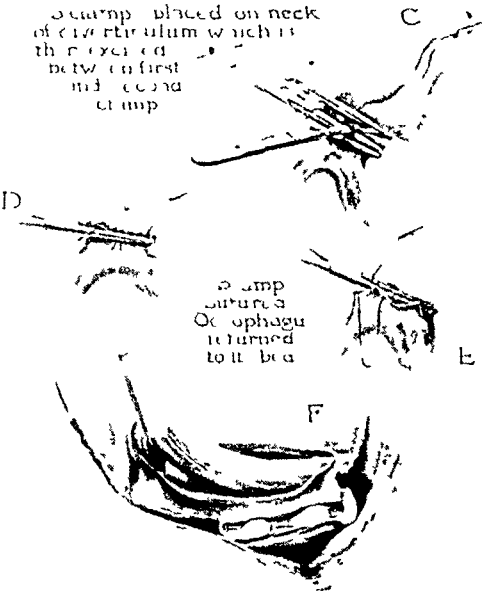



FIG 3

FIGS. 1, 2 and 3.—Operative technic (1) Shows the exposure obtained, (2) the diverticulum freed and held up by clamps; (3) the method of excision and suture.

with cardiospasm and have been regarded as a complication of that condition. Since diverticula are found so rarely in cases of cardiospasm some additional factor must be present in those cases that develop them. It has been suggested that they arise in areas of congenital weakness of the esophageal wall. While it does not exclude a congenital origin the fact that symptoms in this series of cases, all of which were of the pulsion variety, began at 41, 42, 51, 52, 54 and 59 years of age, suggests a degenerative rather than a developmental cause.

To the two main varieties Barrett has added a third—the traction-pulsion diverticula, in which a combination of the etiologic factors is said to exist.

*Symptomatology:* Difficulty in swallowing is the outstanding symptom. It may be noted first in taking liquids or may be most troublesome with solids. Pain is nearly always present beneath the lower sternum or xiphoid and, in addition, may be referred to the interscapular region. Vomiting occurred in half of this series and another had regurgitation. Loss of appetite follows, and the patient begins to lose weight. Weight loss and dehydration, as in Case 2, may be extreme. For the most part the symptoms seem to occur in episodes at gradually lessening intervals. The patient may be entirely free from discomfort for long periods.

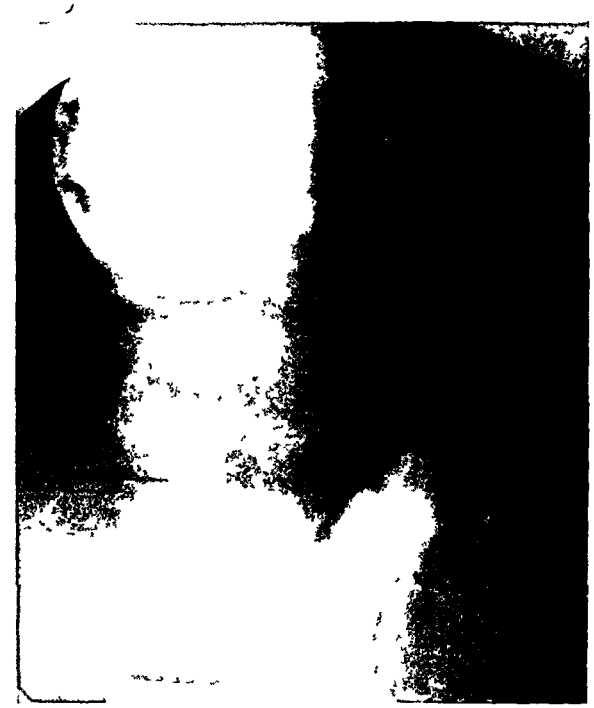


FIG. 4.—Case 2: Preoperative film.

*Diagnosis:* Diagnosis is based upon the clinical history and the barium examination of the esophagus. It was possible in two cases to suspect the condition from the plain roentgenogram, and it is probable that familiarity with the appearance shown in Fig. 11 might result in the condition being recognized by the radiologist when not suspected by the clinician.

*Treatment:* Diverticula discovered accidentally in the course of routine barium meals need no treatment. Those associated with symptoms should be operated upon. Difficulty in swallowing seems to have arisen in some, as in the pharyngo-esophageal variety, by the opening into the pouch becoming the more direct continuation of the lumen of the esophagus and the distended diverticulum pressing upon and distorting the esophagus below the opening. Since the symptoms are often present in episodes only, and may disappear completely for long periods following a short regimen of physical rest and bland diet, they are probably initiated at times by an inflammatory swelling. Despite the knowledge that any one attack may be recovered

from, operation should be advised in large diverticula while the patient is still in good general condition. The danger of ulceration and perforation or hemorrhage has to be considered. When operation has been deferred too long and the patient has become seriously ill through malnutrition and dehydration or suffers in addition from other serious conditions, as was the case in three of these patients, the danger is much increased.

*Operative Procedure:* When present, malnutrition and dehydration should be corrected as completely as possible. This is accomplished most readily by continuous feeding through a duodenal tube. The esophagus and diverticulum should be washed out with a tube on several occasions for 24 hours before operation in order to remove from them all food particles and mucous



FIG. 5.—Case 2: Two months after operation. The removal could have been more complete.

secretions. A duodenal tube in the stomach at the time of operation aids in identification of the esophagus. It should remain in position postoperatively to permit aspiration of fluid and air from the stomach for the first day or two and feeding during the next few days. Swallowing may be permitted on about the fifth day. Intratracheal closed anesthesia should be employed. This is important because if the surrounding tissues are very adherent to the sac the right pleura is easily opened. A posterolateral approach through the seventh or eighth intercostal space has been found satisfactory. As in all operations of similar magnitude, blood should be replaced as lost. The chest should be closed with an intercostal water-seal drain. The systemic use of penicillin for five to seven days postoperatively lessens the danger of

local infection and of pulmonary complications. The details of the operative technic are described in the case reports and illustrated in Figures 1, 2 and 3.

## CASE REPORTS

CASE 1.—Dr. Chas. C., age 60. Admitted July 9, 1934; discharged September 4, 1934.

The patient, a 60-year-old physician, first noticed difficulty in swallowing one year previously. The food seemed to stop in his chest and there was a sense of pressure substernally. Swallowing more food would then give him great discomfort. Later, he had attacks of vomiting which were preceded by nausea and were very severe but lasted only a short time. The material vomited tasted bitter. It never contained blood. He had had pain in the chest for one year. This was at times substernal and at times between the shoulders and seemed to "bore" into the spine. For the last three



FIG. 6.—Case 3: Preoperative film.

months it had been constant. His appetite was good. He had lost 20 lbs. during the three months before admission. He was a chronic alcoholic and had for some time been taking three grains of morphine daily.

Examination revealed a man who looked much older than his years, and who had obviously lost a good deal of weight. The blood pressure was 120/80. The arteries were moderately thickened. The chest was barrel-shaped and there were a few râles at both bases. The abdomen was protuberant but otherwise normal. Barium examination of the esophagus disclosed a saccular diverticulum three cm. in diameter about two inches above the diaphragm.

*Operation—July 23, 1934:* Under intratracheal ether anesthesia, the left chest was opened through the seventh interspace. The mediastinal pleura was incised for three inches in the region of the diverticulum and the esophagus and diverticulum were gently isolated and lifted forward on tapes. The sac arose from the posterior aspect of the esophagus and passed to the right. It was the size of an English walnut, thick-walled, and seemed in a state of contraction. It joined the esophagus by a neck two cm. in diameter. A stomach tube was passed. Three Kocher forceps were placed across the neck of the diverticulum, which was then divided with a cautery between the two distal clamps. The second clamp was removed and the fringe of tissue left oversewn with a running suture of chromic catgut on an atraumatic needle. The third clamp was removed and the first layer of sutures invaginated with a second of a Lembert type. There was no encroachment on the lumen. The divided mediastinal pleura was sutured behind the isolated portion of the esophagus in order that infection, if it should occur, would involve the pleural cavity and not the mediastinum. The chest was closed leaving a water-sealed intercostal drain to the site of operation.

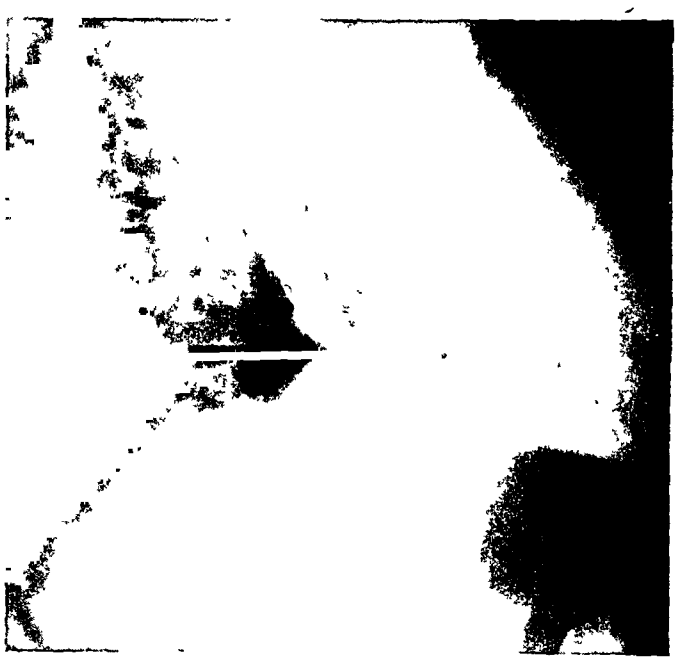


FIG. 7.—Case 3: Five weeks postoperative. Difficulty in swallowing due to cardiospasm.

*Pathologic Report:* The specimen consisted of a thick-walled sac three and one-half cm. in depth and three cm. across at the point of division. Microscopically (Fig. 4), the wall was composed of a layer of fibrous tissue, a rather thick layer of smooth muscle and a lining of squamous epithelium in which at one place was an old, partially healed ulcer. There were many chronic inflammatory cells in the submucosal zone.

*Postoperative Progress:* Convalescence was rather stormy, and for a short period of about ten days there was an esophageal fistula along the site of the drainage tube. There was a small effusion, but no infection of the general pleural cavity occurred. Management was rendered difficult by the morphine addiction. Barium examination, September 5, 1934, showed an apparently normal esophagus, it being impossible to recognize any definite defect at the former site of the diverticulum. The patient was eventually cured of the morphine addiction and survived nine years without symptoms referable to the esophagus.

CASE 2.—James C., male, age 58. Admitted June 26, 1944; discharged August 29, 1944.

In 1923, he had a gastro-enterostomy performed for duodenal ulcer. After five or six years of complete comfort he began to have episodes of pain beneath the xiphoid following the taking of food. These attacks became more severe as time passed and during the last year had been much more frequent and much worse. For the past month he had been in continuous trouble. The pain came on immediately following food and he often had to leave the table to vomit. The vomitus tasted bitter. He had lost an estimated 25 lbs. in weight and had become pale and weak. The diverticulum had been recognized in roentgenograms taken in 1942.

On examination, the patient was very thin, very pale and dehydrated. The abdomen was scaphoid and there was a scar of a well-healed upper right rectus incision. Examination of the anterior chest was negative but posteriorly there was a distinct area of dullness to the right of the seventh and eighth dorsal vertebrae. Percussion

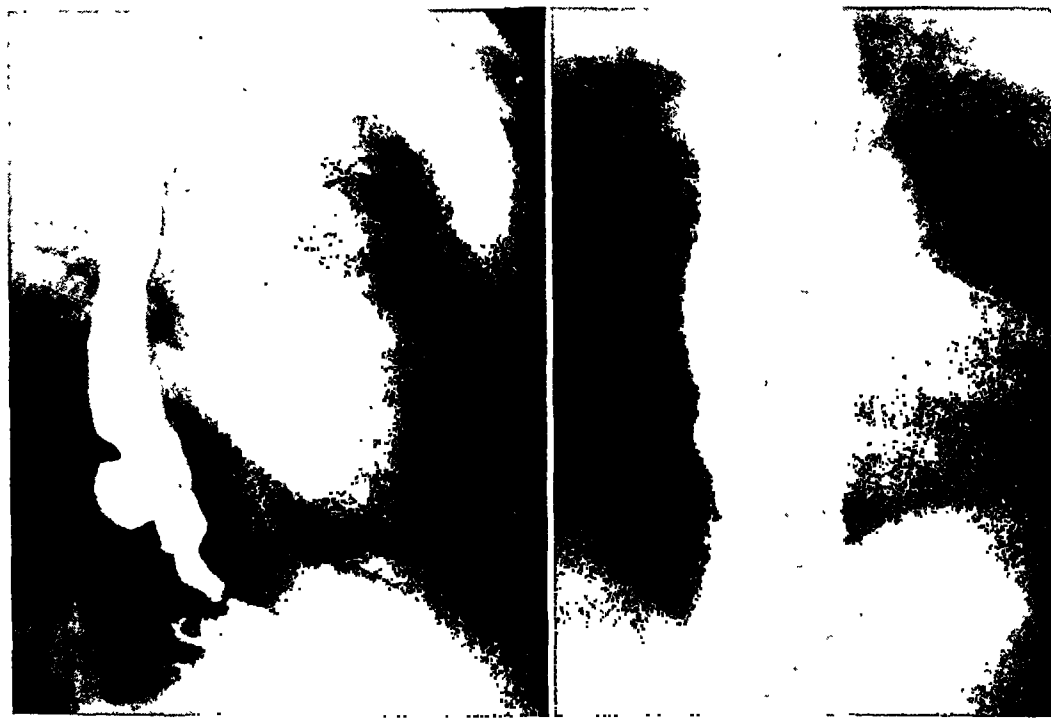


FIG. 8-A FIG. 8-B

FIG. 8.—A and B.—Case 3: March, 1946. Some dilatation of esohpagus remains together with a bulge where diverticulum removed. No interference with function.

over this area was painful and elicited from the patient "that's it." There was a slight but definite generalized enlargement of the superficial lymph nodes. A diagnosis of chronic lymphatic leukemia was made by a consulting physician. The roentgenograms (Fig. 4) showed a diverticulum about three inches in diameter arising apparently from the posterior aspect of the esophagus about two inches above the diaphragm and pointing to the right.

Despite the diagnosis of lymphatic leukemia and the fact that because of this and the state of malnutrition he was a poor operative risk, it seemed that operation should be undertaken. A duodenal tube was passed into the stomach without difficulty and he was fed a high protein mixture by continuous drip for a little more than a week. During this period his weight increased 11 lbs., and he felt and looked much better.

*Operation—July 7, 1944:* Under intratracheal ether anesthesia, the left chest was opened through the seventh interspace, using a posterolateral approach. The mediasti-

nal pleura was incised along the posterior margin of the lateral ligament of the lung. The esophagus was exposed just above the diaphragm and a tape placed about it, and a similar procedure was carried out just below the root of the lung. By lifting on these tapes it was possible to bring the intervening portion of the esophagus forward and to the left and begin the dissection of the diverticulum. It was moderately adherent to the surrounding structures including the right pleura and the right vagus nerve, the latter being removed on its surface. When freed, the sac was seen to arise from the posterior aspect of the esophagus about three inches from the diaphragm. It was removed and the cut-surface oversewn, as in Case 1. In addition, a covering of adjacent areolar tissues was provided. The divided pleura was again closed behind



FIG 9—Case 4: Preoperative film.

the isolated portion of esophagus The chest was closed leaving a water-sealed intercostal drain through a stab wound in the ninth interspace in the posterior axillary line. The operation was well-tolerated

*Pathologic Report:* The specimen consisted of a sac-like structure 7 x 4 5 cm. The wall measured approximately two mm. in thickness. Microscopically, it was formed of squamous epithelium, submucosa, muscularis mucosa and a thick layer of fibrous tissue. Many chronic inflammatory cells were seen in the submucosal area. The muscle fibers were separated into bundles and did not form a continuous layer.

*Postoperative Progress:* The duodenal tube was left in place and feedings con-

tinued through it until it was removed on the 13th day. Tube feeding was continued longer than usual because of the poor state of nutrition. The intercostal drain was removed on the third postoperative day. There was a great deal of trouble in clearing bronchial secretions and some pulmonary atelectasis and infection. A rather late, and not very active, streptococcus infection of the chest wound occurred which required drainage, but cleared fairly rapidly when it was possible to obtain penicillin for systemic use. He swallowed well after removal of the tube. Recovery was slow.

Barium examination of the esophagus, August 29, 1944, showed that the opaque material passed into the stomach readily and without obstruction to its flow. At the site of the former diverticulum was a small pocket, indicating that removal had not been quite complete (Fig. 5).

This man was a very poor operative risk because of starvation and the associated leukemia. He was relieved of esophageal symptoms and remained comfortable and

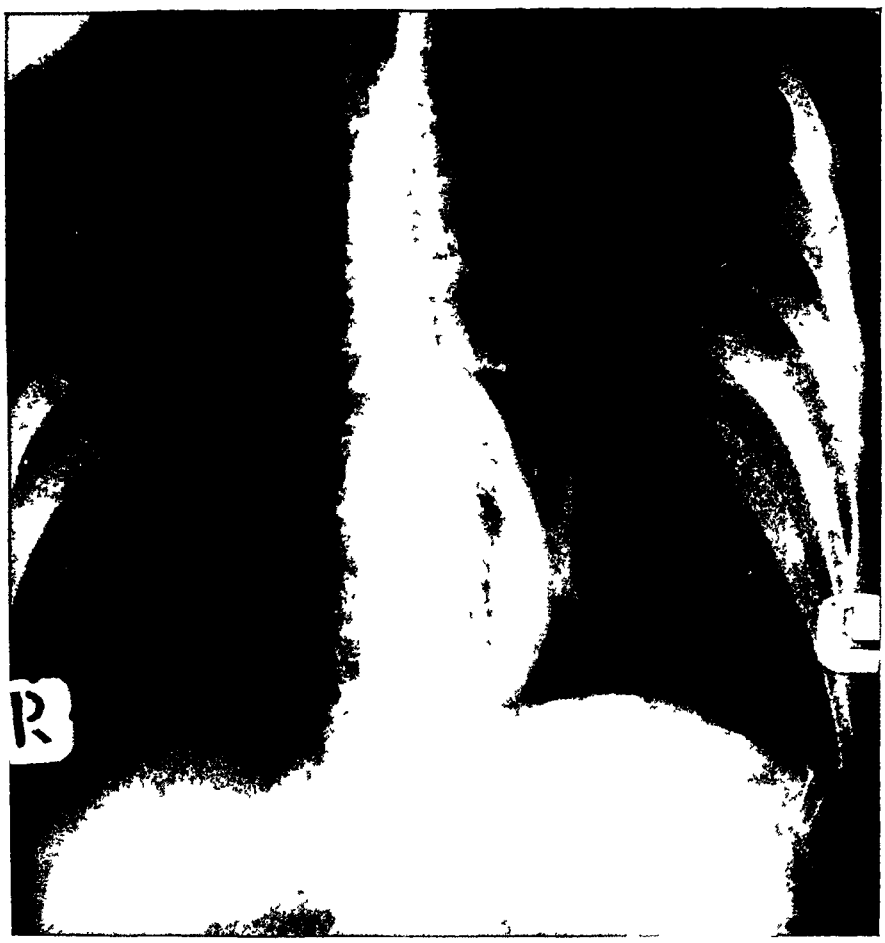



FIG 10.—Case 4: March 1, 1946. Esophagus normal apart from displacement into chest.

relatively well until admitted to the local hospital, May 5, 1945, with severe epistaxis from which, in spite of transfusions, he died.

CASE 3.—Henry G., male, age 55. Admitted January 8, 1945; discharged March 2, 1945.

One year before admission he began to notice difficulty in swallowing water and that when he lay down, particularly upon the left side, the water regurgitated into his mouth. Solid foods then began to stick and to be returned sour. During the attacks there was discomfort beneath the lower end of the sternum. He had been admitted to the medical wards in August, 1944, at which time a diagnosis of moderately advanced bilateral tuberculosis, nonbacillary, had been made. The plain roentgenograms

of the chest had shown a fluid level to the right of the spine, and a subsequent barium examination had disclosed a diverticulum of the lower portion of the esophagus. Since treatment of the tuberculosis seemed the more urgent matter he was transferred to a sanatorium. The tuberculosis improved but the difficulty in taking food was thought by the sanatorium physicians to be interfering with his recovery. He was returned to the general hospital, therefore, for operation.

The patient was a strongly built, moderately well-nourished man. Clinical examination was negative so far as the esophagus was concerned. Medium and low-pitched râles and some rhonchi were heard over both sides of the chest in the apical and midlung fields. Roentgenograms of the esophagus showed a diverticulum more than three inches in diameter, which seemed to arise about two inches above the diaphragm and pass to the right (Fig. 6).

*Operation—January 15, 1945.* The operative procedure was essentially the same as carried out on Cases 1 and 2. Because the postoperative roentgenologic examina-



FIG. 11



FIG. 12

FIG. 11.—Case 5: Plain film showing diverticulum with fluid level to right of spine.
FIG. 12.—Case 5: Diverticulum filled with barium.

tion in Case 2 had suggested that removal of the diverticulum might have been somewhat more complete, the clamps were placed a little closer to the esophagus.

*Pathologic Report:* The specimen consisted of a moderately thick-walled sac measuring eight cm. in its greatest diameter. Microscopically (Fig. 5), the wall was formed of squamous epithelium, submucosa and a thick layer of fibrous tissue. There was a moderate number of chronic inflammatory cells in the submucosal zone. No muscle tissue was seen.

*Postoperative Progress:* Recovery from operation was uneventful, but some difficulty in swallowing and a feeling of substernal fullness remained. Barium swallow on February 8th showed narrowing of the lower end of the esophagus with interference with the passage of the mixture and dilatation of the esophagus proximal to this. A second barium swallow on February 19th (Fig. 7) showed that the obstruction was apparently at the cardia. On February 25th, the cardia was dilated with bougies. Following this the patient was able to swallow without difficulty and on March 1st a barium mixture passed without difficulty. There has been no recurrence of symptoms.

A recent roentgenogram (Fig. 8) showed considerable spasm of the esophageal wall and a bulge in the area from which the diverticulum had been removed but the patient swallows easily and has gained 25 lbs. in weight.

CASE 4.—G. S. W., male, age 57.

Symptoms of indigestion, in the form of pain in the xiphoid region, began in 1942. The distress usually appeared on first taking food but sometimes not until halfway through a meal. He had attacks which lasted from a few hours to a few days, never more than a week, and had periods as long as a month of complete comfort. There was marked loss of appetite and strength, and his weight had dropped from 167 to 147 lbs. There was no vomiting.

Clinical examination was negative insofar as the esophageal lesion was concerned. Roentgenograms showed a diverticulum (Fig. 9) of the lower esophagus, about two to three inches in size. It arose by a relatively narrow neck about three inches above the diaphragm.

*Operation—April 26, 1945:* The operative procedure was, again, essentially similar.

*Pathologic Report:* The specimen consisted of a rather thick-walled sac lined with grayish mucous membrane. Microscopically, there was an inner layer of squamous epithelium, a submucosal zone in which there were many chronic inflammatory cells and a thick outer coating of fibrous tissue. Patches of muscularis mucosa remained.

*Postoperative Progress:* Recovery was uneventful. The patient has been relieved of symptoms. A recent roentgenogram (Fig. 10) showed an apparently normal esophagus except that the portion behind which pleura was sutured is displaced to the left.



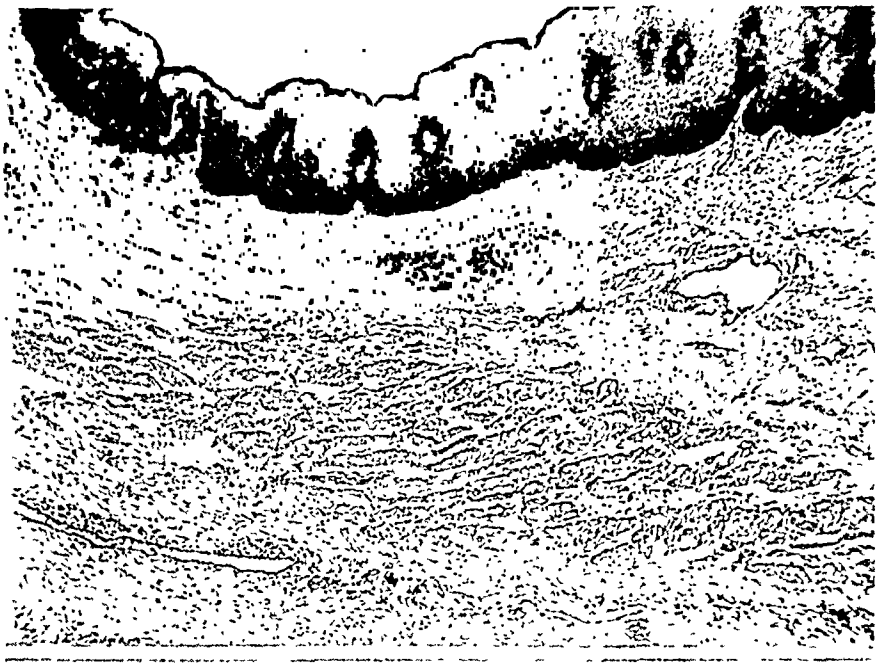
FIG. 13.—Case 6: Diverticulum when symptoms present.

CASE 5.—Bessie W., female, age 45.

This woman, a vagrant, first presented herself at an Out-patient Clinic, October 21, 1942, complaining of difficulty in swallowing which had begun three weeks previously, and from which she had almost recovered. It was described as an obstruction "which comes and goes." The Wassermann reaction was found to be strongly positive and she was referred for treatment. No special attention was given to the difficulty in swallowing. She reappeared in March, 1943, with the same complaint and, again, in April, 1943, requesting that she be placed on relief because of "stomach trouble." She stated that she now had attacks during which the food stuck in her chest and would not go into the stomach. The food was vomited, giving relief. On May 18, 1945, she returned to the clinic complaining that in addition to difficulty in swallowing she now had chronic cough and sputum. A roentgenogram of the chest was taken and, in reporting on this, the radiologist called attention to a fluid level in the lower chest to the right of the midline, and suggested an examination of the esophagus. She was finally admitted to the medical wards, July 12, 1945, in a state of acute alcoholism complicated by bronchopneumonia. The radiologist's report upon the films of the chest made at that time is interesting (Fig. 11): "Situated on the right side and overshadowed by the cardiac outline there is a smooth opacity having a convex lateral and inferior border and projecting from the shadow of the thoracic spine for a dis-

tance of two cm. It is ten cm. in vertical height, with a fluid level superiorly." Subsequent examination of the esophagus disclosed the very large diverticulum (Fig. 12) which again arose from the posterior surface and projected to the right. It was deemed unwise to operate upon this patient.

FIG. 14



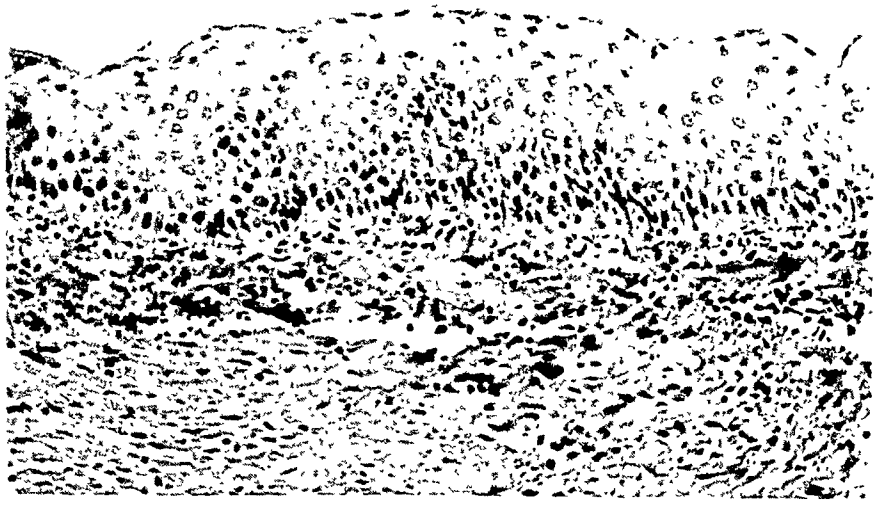


FIG. 15

FIG. 14.—Case 1: Photomicrograph (x/55), showing well-developed muscularis mucosa.

FIG. 15.—Case 3: Photomicrograph (x/160), no muscle could be recognized.

CASE 6.—Joseph T., male, age 51. Admitted March 13, 1945; discharged March 16, 1945.

This man, a laborer, was in good health until four and one-half months before

admission, at which time he began to have a feeling of distention after meals and aching in the epigastrium. The latter had increased in severity and had been accompanied, latterly, by distress in the interscapular area. He had lost appetite, tired easily, and his weight had decreased by 15 to 20 lbs. There had been no vomiting.

Physical examination gave no clue to the nature of the disability. Barium examination of the esophagus disclosed a large diverticulum arising just below the lung root and projecting to the right (Fig. 13).

The patient left hospital with the expectation that he would return for operation, but after several weeks' rest the symptoms disappeared, his appetite returned and he regained the lost weight. When last heard from he was free from symptoms and working. It is probable that with a return of symptoms he will require operation.

## SUMMARY

Six diverticula of the lower esophagus have been reported, four of which were operated upon. The condition is uncommon, but should be considered as a possible cause of difficulty in swallowing and substernal distress. Those responsible for symptoms and possibly all of what may be described as giant diverticula should be operated upon. In spite of the fact that only one of the four cases operated upon could be considered a good operative risk, no patient died as a result of operation. The routine postoperative use of penicillin should decrease the danger of infection.

I should like to thank Dr. N. S. Shenstone, who operated upon two of the patients, for the privilege of including them in this report and Dr. Roscoe Graham for his permission to report one of the cases not operated upon. My thanks are also due to the Department of Pathology for the preparation of the photomicrographs and to the Department of Medical Art for the drawings illustrating the operative technic.

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[2] Smith, Lester A.: Diverticula of the Thoracic Esophagus. Am. Jour. of Roentgenology, 19, 27–35, 1938.

[3] Vinson, Porter P.: Diverticula of the Thoracic Portion of the Esophagus: Report of 42 Cases. Archives of Otolaryngology, 19, 508–513, 1934.

DISCUSSION.—DR. STUART W. HARRINGTON, Rochester, Minn.: I have greatly enjoyed Doctor Lahey's presentation of pharyngo-esophageal diverticulum and wish to compliment him on the excellent results obtained with his two-stage diverticulectomy. I agree with Doctor Lahey's statement that pharyngo-esophageal diverticula may be treated surgically by a one-stage or two-stage operation. I have been interested in this subject for some time. My first experience was with the two-stage operation, which was the method of treatment utilized by Doctor Judd when I assisted him 30 years ago. My own experience consists of 171 of the 348 pharyngeal operations which have been performed at the Mayo Clinic for this condition. Of these 171 operations, the first 25 were done in two stages and the remaining 146 were done as one-stage procedures.

There was one operative death in the 25 cases in which a two-stage operation was performed. A temporary pharyngeal fistula developed in six cases. Paralysis of the left vocal cord developed in one case and repeated dilatation was required in five cases

because of angulation of the esophagus. The average period of convalescence to the time of dismissal was five weeks. Diverticula of moderate size recurred in three cases but repeated dilatation has produced relief and a second operation has not been necessary.

The one death can hardly be attributed to the type of operation as the patient was in very poor general condition because of Parkinson's disease and had almost complete obstruction of the esophagus, which necessitated operation. It is probable that the patient would not have survived any type of operation. I believe that the three recurrent diverticula and the prolonged convalescence in the six cases in which pharyngeal food fistulae developed were due to the technical difficulties of accurately determining the site of the neck of the diverticulum and to delayed healing resulting from the first stage operation. I thought these difficulties would be lessened and the results improved by a one-stage operation.

I have been much gratified with the results obtained in the 146 cases in which a one-stage operation was performed, particularly because mediastinitis has not developed in any case and because the wound healed by primary intention in 92 per cent of the cases. There was no operative mortality. The diverticula recurred in two cases and a second operation was necessary in one. There were five temporary fistulae and one instance of paralysis of the left vocal cord. Repeated dilatation was required in five cases because of angulation of the esophagus. The average duration of convalescence to the time of dismissal was 19 days.

I have been particularly interested in the cases in which the diverticula recurred. In three of the seven cases in which this happened, I believe that one of the reasons for the recurrence was the method of approach to the diverticulum. In these three cases, the approach was through a left cervical incision and the opening of the diverticulum was chiefly on the right side of the hypopharynx. I have found that in a high percentage of pharyngo-esophageal diverticula, the opening is chiefly on the right side of the hypopharynx. In these diverticula, the surgical approach should be made through the right cervical region, because a more accurate dissection of the neck of the sac can be accomplished. Also, there is less danger of leaving a spur at the site of the opening of the diverticulum. A right cervical approach was employed in 34 of the 171 cases.

The chief considerations in determining the relative value of these two operative procedures are the operative mortality, the effectiveness of the procedure in relieving the pathologic condition and the associated morbidity, which is of relatively little importance as compared with the mortality.

I believe that the results obtained with the two types of operation in this series of 171 cases of pharyngo-esophageal diverticula definitely show the value of the one-stage procedure.

I have also enjoyed Doctor Janes' presentation of the treatment of diverticula of the lower part of the esophagus and I agree with his method of surgical treatment by transpleural diverticulectomy. As he has stated, these diverticula are usually situated in the lower fourth of the esophagus and are relatively rare as compared with pulsion diverticula of the hypopharynx, commonly called pharyngo-esophageal diverticula.

I have operated upon four patients who had a pulsion diverticulum of the lower part of the esophagus. In each of the four cases, I performed a one-stage transpleural diverticulectomy. In three of the cases, I was able to excise the diverticulum completely and reconstruct the wall of the esophagus. In one case, it was impossible to excise the diverticulum completely because of extensive calcification of its walls, which was most pronounced at the neck of the sacculation, but it was possible to excise part of the diverticulum, which relieved the obstructive symptoms caused by an angulation of the esophagus just below the diverticulum.

One of the important technical considerations is the inversion of the mucous membrane at the neck of the diverticulum. The technic I have used is to excise the diverticulum with a cautery about 1.5 cm. from the wall of the esophagus and to invaginate

the 1.5 cm. of mucous membrane of the neck of the diverticulum with a continuous mattress suture of chromic catgut. The wall of the esophagus is then closed over this invaginated mucous membrane with interrupted silk sutures. The mediastinal pleura is then sutured over this closed portion of the esophagus.

In the four cases in which I have operated, there have not been any operative deaths. Postoperative empyema developed in one case but drainage was followed by a satisfactory recovery.

I have some slides which show the different locations of the diverticula emphasizing the importance of approaching the right-sided diverticulum through the right cervical incision.

Dr. Robert S. Dinsmore, Cleveland, Ohio: I think it is unfortunate that Doctor Lahey did not have more time to bring out some of the points in this problem. Mention has been made of mediastinitis, but a review of a large series of cases done by either the one- or two-stage operation shows that the incidence of this complication is lower than is generally supposed. Lord Moynihan had early made this observation. Neither essayist made any mention as to the use of a scope at the time of operation. I prefer to do them without a scope in place. I had one experience which impressed me; after closing the neck of the sac in the esophageal wall the scope inadvertently passed through the closed suture line.

I do not think we should disregard the fact that there may be a modified two-stage operation which can be used. If there has been gross contamination, by simply placing a small gauze pack in the area a secondary closure can be done at the end of a 48-hour period. Some of these large sacs, particularly the ones which pass down into the mediastinum, the walls of which become the thickness of paper tissue, may require even more than a two-stage operation. Occasionally one of these may become infected and require more than a two-stage operation. I once helped Doctor Crile with one of these cases, and each time we would open the neck we would get into a sacculated collection of pus. The patient, however, was coöperative, and aided us by inserting about 600 cc. of corn whiskey into the cavity, which apparently helped to sterilize it.

Dr. Frank H. Lahey, Boston, Mass. (closing): Visitors at the Clinic often ask me why we do not leave these cases as they are when the first stage is completed, that is, with the sac suspended. We have done this in four cases and there has been recurrence of the sac enlarging into a dependent position, obstructive, with regurgitation symptoms in all four cases.

Whether you do esophageal diverticula in one or two stages, I am quite sure that how thoroughly you dissect the sac, how carefully you free it of muscle and how accurately you ligate its neck flush with the longitudinal esophagus have a great deal to do with nonrecurrence. We have in the last 60 cases either sutured or tied the sac under good visualization accurately at its junction with the longitudinal esophagus. As stated in the paper, it is easy to ligate them accurately at the second stage; they heal by first intention in most cases, but in a few there has been leakage. It is because of the fact that leakage occurs occasionally after ligature or suture, either in a one- or two-stage procedure, that we have done these all in two stages. I cannot avoid being disturbed by the presence of a large mediastinal cavity when large sacs are removed and the uncertainty of possible leakage exists.

I do not think it at all necessary to use an esophagoscope in operating upon these patients. When you visualize the sac you can do everything without the esophagoscope that you can do with it, and the procedure is much less complicated.

Concerning the cases reported by Doctor Janes in which the diverticulum occurred within the pleural cavity above the diaphragm, we have reported five such cases operated upon with no fatality. Almost all of these patients are elderly. In the article in which these cases were published I reported the method by which the sac can be completely mobilized so that it hangs by the neck and then can be attached to the parietal pleura in the vertebral gutter beside the vertebral bodies, so that the pulled out sac is

exactly parallel with the esophagus and so that in the upright position no food can enter it. We have demonstrated that upon giving patients barium it is possible to get the barium into the sac only with the patient in the Trendelenburg position. This is the method whereby one can overcome the effects of the diverticulum without the danger of possible pleural contamination in these elderly people.

DR. ROBERT M. JANES, Toronto, Ont. (closing): There was no operative mortality in this group, in spite of the fact that one had lymphatic leukemia, one was a morphine addict, and one had bilateral pulmonary tuberculosis.

# CARCINOMA OF THE MIDTHORACIC ESOPHAGUS*

## ITS TREATMENT BY RADICAL RESECTION AND HIGH INTRATHORACIC ESOPHAGOGASTRIC ANASTOMOSIS

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ANY OPERATIVE PROCEDURE which is intended to be applied in the treatment of carcinoma of the esophagus, at whatever level, must be based upon the two-fold aim of prolongation of life, looking towards the possibility of cure, and the provision of relief from the distress which results from the obstruction produced by the growth.

Until recently the only practical method available for use in the removal of a carcinoma located in the middle half of the thoracic portion of the esophagus was the Torek operation.[1] This procedure has, however, been shown to be unsatisfactory when measured by the above criteria.

In the first respect, the Torek operation is inadequate as a cancer operation. It is a well-established principle in the treatment of carcinoma that in addition to a wide excision of the primary tumor, it is essential to remove as large a number of the regional nodes as possible. If Torek's original technic is followed, two important groups of regional lymph nodes are not removed. These are the subdiaphragmatic paracardial nodes and the group of nodes found in relation to the left gastric vessels. Both of these groups, in addition to those located around the lower thoracic portion of the esophagus, are frequently involved by metastases (Table I). The importance of removing these nodes in the performance of the operation is confirmed by the fact that they were found to be involved in 50 per cent of the cases in this series of 32 radical resections. It is only the lower thoracic nodes which are removed in the classical Torek operation.

TABLE I

CARCINOMA OF THE MIDTHORACIC ESOHPAGUS

*Frequency and Distribution of Lymph Node Metastases in 32 Patients who had Resection and Anastomosis*

| | |
|---|---|
| Nodes not involved | 9 |
| Nodes involved | 23 |
| Hilum of lung | 7 |
| Peri-esophageal | 15 |
| Paracardial | 13 |
| Near left gastric vessels | 16 |

In the second place, the failure of the Torek procedure to provide satisfactory palliation, even if an external esophagoplasty is successfully completed, is obvious to those who have had experience with its use.[2] Table II summarizes the results obtained from the application of the Torek procedure in

*Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

TABLE II

EXPERIENCE WITH THE TOREK OPERATION AT THE MASSACHUSETTS GENERAL HOSPITAL

| | |
|---|---|
| Number of operations | 14 |
| Postoperative deaths | 2 |
| Survivals | 12 |
| External esophagus not begun (all patients dead) | 4 |
| External esophagus begun | 8 |
| Died before completion | 4 |
| External esophagus completed | 4 |
| Died subsequently | 3 |
| Alive and well | 1 |

14 cases of carcinoma of the midthoracic esophagus. The immediate postoperative mortality is not prohibitive (two cases). But its poor result from the standpoint of cure is evident from the fact that all but one patient have died of metastatic or recurrent disease. The unsatisfactory palliative result is reflected by the fact that of the eight patients in whom an external esophagoplasty was begun, four died of metastases before the procedure could be completed. Of the remaining four in whom the external esophagus was finally established, two died soon after the completion of the surgical program. Of the two who remained well, one has since died and one is alive and well almost six years after the operation. These results are far from satisfactory.

The development of a satisfactory technic for the radical resection of the local disease, including the excision of at least three of the four groups of regional nodes which may be invaded, offers greater promise of producing a cure in these cases. But of equal, if not greater, importance is the fact that after a high primary intrathoracic esophagogastric anastomosis has been performed, the patient is able to swallow normally. The palliation afforded by this procedure, even if death should occur six months to a year, or more, later as a result of distant metastases, makes this operation infinitely superior to the Torek procedure.

## DESCRIPTION OF THE OPERATION: ESOPHAGECTOMY FOLLOWED BY HIGH INTRATHORACIC ESOPHAGOGASTRIC ANASTOMOSIS

Intratracheal ether-oxygen anesthesia is used. The patient is placed on his right side with the left arm held forward, the hand in front of his face. The left side of the chest is made to arch upwards by bending the operating table at an angle. Intravenous infusions of saline and transfusions of blood are given as necessity demands during the procedure, using a hand or forearm vein. The incision is started at the left costal margin anteriorly and extends posteriorly over the course of the eighth rib, curving upwards a short distance between the spine and the left scapula. The eighth rib is resected, cutting its neck posteriorly and the cartilage anteriorly. It is usually necessary to divide one or more ribs posteriorly (often the seventh, sixth, and fifth) in order to provide access to a high growth and for the performance of a very high anastomosis. The wound edges are protected with large gauze pads, a rib-spreader is inserted, and the lung is retracted using a Harrington retractor over a protecting pad of gauze.

The resectability of the growth must be determined next. The mediastinal pleura is incised and the dissection is begun anterior to the esophagus, so as to free the attachments of the growth to the structures in the hilum of the lung. At this point, invasion of the left main bronchus, extensive involvement of the region around the inferior pulmonary vein, or fixation to the aortic arch may make it impossible to remove the tumor. If the adhesions to these structures can be divided safely, the dissection of the posterior attachments is then begun. This step in the procedure is left until last so as to avoid interference with the blood supply to the midesophagus which would result from dividing one or more of the esophageal arteries which arise from the aorta. Extensive fixation to the aorta or actual invasion of its wall makes it necessary to abandon the operation in some cases. After the posterior attachments are divided, the growth must be freed from the right mediastinal pleural reflexion. In many cases it is necessary to excise a portion of this pleural layer, thus, leaving a wide opening into the right thoracic cavity. The anesthetist's closed system makes it possible to prevent collapse of the right lung by exerting positive pressure and no attempt need be made to close the right pleural cavity. In the majority of such cases the defect is too large to be closed and after the left lung has been expanded and the chest closed, no ill effects have been observed as a result of leaving it open. It was necessary to open the right pleural cavity in 13 of the 32 cases reported. No complications which could be attributed to this occurrence were observed. In a few cases small portions of the adjacent lower lobe of the right lung have been removed because of fixation to the growth at that point. The defect in the surface of the lung is closed with a running suture of fine No. 00 catgut on an atraumatic needle.

After the esophagus has been dissected free from the level of the aortic arch downwards to its fullest extent, the abdomen is entered by incising the diaphragm from the insertion at the costal margin through the esophageal hiatus. The phrenic nerve is crushed to maintain immobility of the diaphragm. The numerous branches of the phrenic artery which are severed in the making of this incision are then tied with suture ligatures. The upper two-thirds or more of the stomach are then freed in order to make it possible to move the fundus to a high level within the chest for the anastomosis. The gastrolienal ligament is divided and the left gastro-epiploic vessels and the vasa brevia are cut and tied. The spleen is protected with gauze and retracted. The gastrocolic omentum is divided as far as the pylorus, taking care to avoid injury to the right gastro-epiploic vessels. The attachments of the cardia and lower esophagus are then cut, including several small vessels which are branches of the superior suprarenal, inferior phrenic, and pericardiophrenic vessels. The gastrohepatic ligament is cut next. Occasionally an artery of appreciable size is encountered in this structure. This vessel is an hepatic branch of the right inferior phrenic artery. Finally, the left gastric vessels are cut and tied close to the origin of the artery from the celiac axis. After this vessel has been severed, the fundus of the stomach can be placed without difficulty in the apex of the chest (Fig. 1, insert).

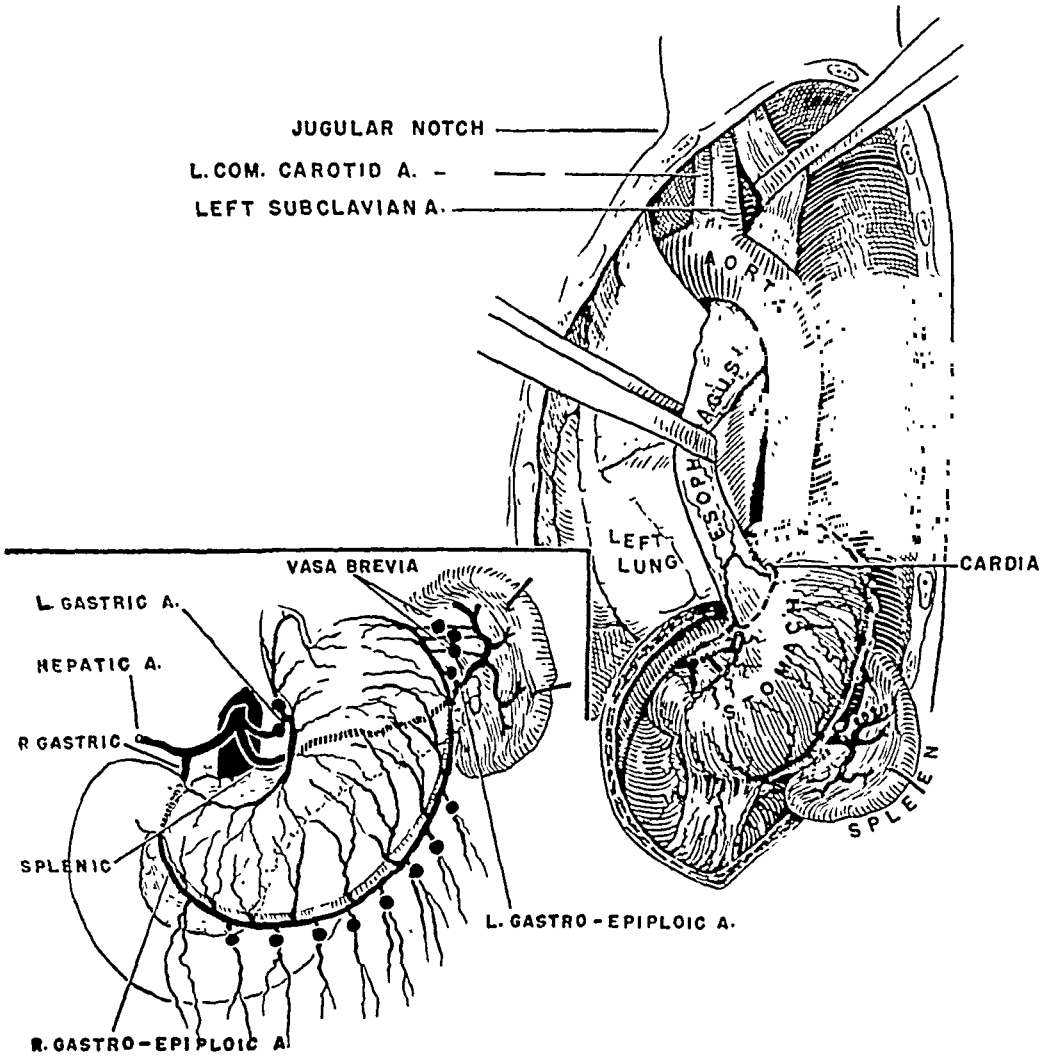



FIG. 1.—Dissection required for esophagectomy and high supra-aortic intrathoracic esophagogastric anastomosis. Complete mobilization of the esophagus to the apex of the chest. Mobilization of the stomach leaving only the right gastric and gastro-epiploic arteries. Inset: Large dots show the blood vessels which must be severed.

The stomach is now divided between clamps just distal to the cardia in such a way as to make it possible to remove the lymph nodes located around the lower esophagus and cardia and those in relation to the left gastric vessels. The distal portion is inverted by means of two layers of continuous sutures of fine chromic catgut reinforced with a layer of interrupted silk sutures. A rubber glove is tied over the lower end of the esophagus.

After the mobilization of the stomach has been completed, an incision is made in the mediastinal pleura above the aortic arch. The portion of the esophagus which lies in the superior mediastinum is now freed by blunt dissection and a piece of Penrose drain is passed around it for traction. By dissection, now from above, now from below, the attachments of the esophagus behind the aortic arch are freed. At this point, several small arteries, some

of which arise from the aorta and some from the bronchial arteries, must be divided. These constitute the last of the esophageal blood supply which arises from within the chest itself. If the growth is very adherent behind the aortic arch, greater exposure may be obtained by cutting the upper one or two left intercostal arteries. The aortic arch may then be retracted forwards sufficiently to complete the dissection behind it. The thoracic duct may be encountered behind or just above the aortic arch at this level. It should be carefully sought for and tied if injured or if it is necessary to resect a portion which may be adherent to the tumor. After the esophagus has been freed in this way, it may be pulled up from behind the aortic arch and turned outwards in a position convenient for the performance of the anastomosis (Fig. 2).

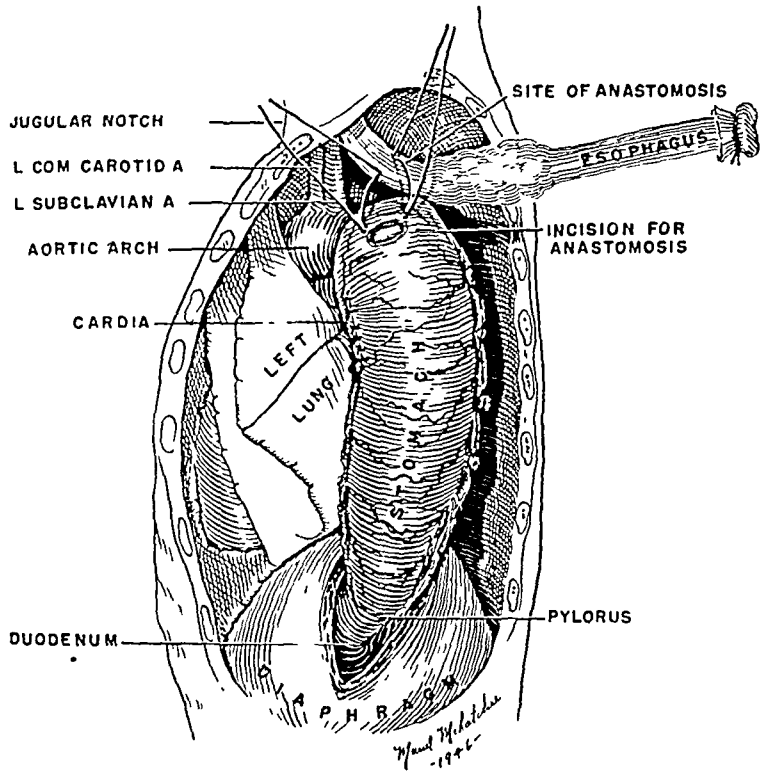



FIG. 2.—Stomach and esophagus completely mobilized and in position for the performance of anastomosis above the aortic arch.

In some cases where the upper limits of the tumor do not extend quite as high as the inferior margin of the aortic arch, dissection behind and above the arch is avoided and the anastomosis is performed just below the arch.

At a high level on the fundus of the stomach a circular incision of appropriate size is made through the serosal and muscular coats. The small vessels which cross this incision in the submucosal layer are tied with suture ligatures of fine silk in order to diminish the amount of bleeding during the performance of the anastomosis. A suitable site for the anastomosis is then chosen several centimeters above the upper limits of the growth, and an outer layer of mattress sutures comprising the first layer of the posterior half of the anastomosis is placed and tied (Fig. 2). A Wertheim clamp is then

put on the esophagus several centimeters distal to the site of anastomosis and with a right-angle knife blade (Beaver blade No. 14) the muscularis of the posterior esophageal wall is incised. The resulting muscle edge of esophagus is then sutured to the muscle edge of the stomach. The posterior half of the esophageal mucosa is then incised and the circular portion of stomach outlined by the initial incision through the serosa and muscularis is excised. The gastric contents are aspirated. The posterior mucosal layer of sutures is then

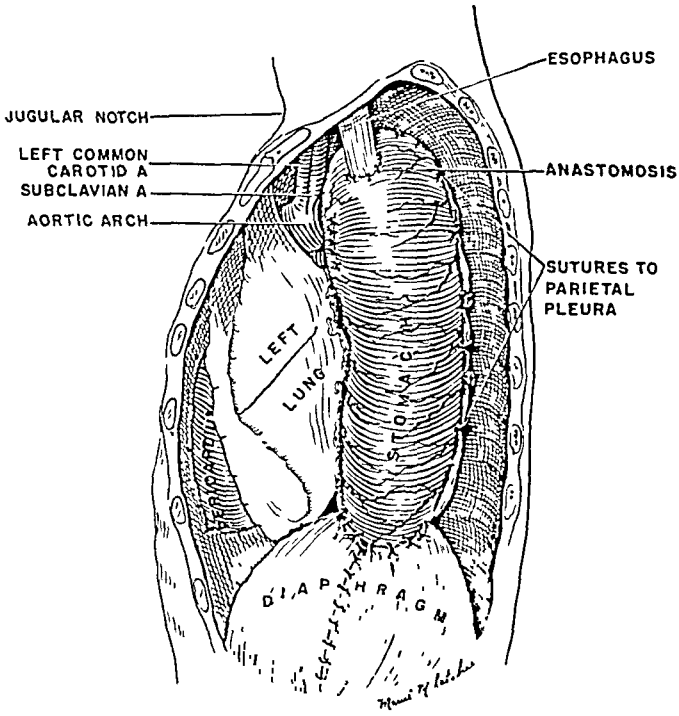



FIG. 3.—Operation completed; anastomosis established; stomach fastened in the chest by sutures to the parietal pleura; diaphragm closed.

applied. With a pair of scissors having bent blades the anterior wall of the esophagus is cut across and the segment to be excised is removed. The anterior aspect of the anastomosis is then completed with three layers of sutures. Fine silk is used throughout. A series of interrupted sutures is used to fasten the stomach to the parietal pleura so as to relieve the pull upon the anastomosis. The edges of the diaphragm are then fastened to the antral portion of the stomach where it passes through and the remainder of the edges of the diaphragm are approximated (Fig. 3).

A solution of penicillin containing 50,000 units is injected partly above and partly below the diaphragm before its closure is complete. A catheter for closed suction drainage is brought out through a short incision in a lower interspace posteriorly and the wound is closed by a careful anatomic approximation of its layers using interrupted silk sutures. The lung is fully expanded before closure of the chest is completely air-tight.

## IMPORTANT DETAILS OF TECHNIC

(1) *Immobilization of the Stomach:* The extensive dissection described, including division of the gastrocolic, gastrolienal, and gastrohepatic ligaments, the left gastro-epiploic, and the left gastric arteries and vasa brevia, is required in all cases where the high level of the tumor makes it necessary to place the fundus of the stomach above the level of the aortic arch. A further reason for cutting the left gastric artery at its origin from the celiac axis is the necessity for removing all the lymph nodes which are grouped about the ascending branches of this vessel.

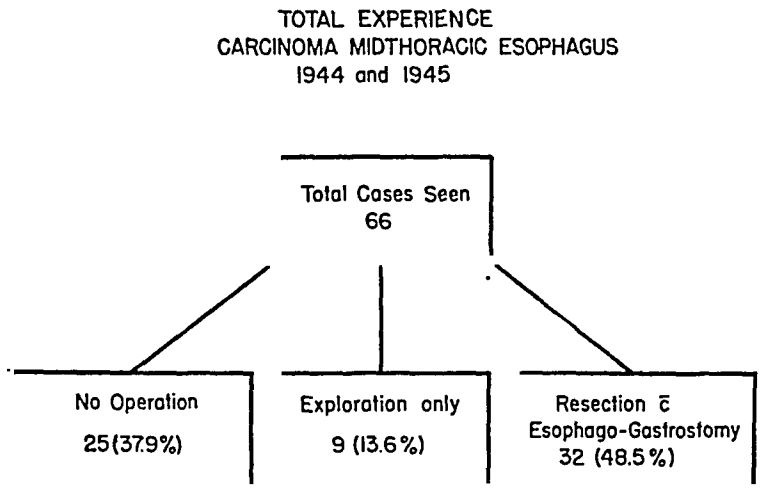



CHART I

(2) *Preservation of the Blood Supply:* (A) At the completion of the operation the stomach is dependent for its blood supply upon the flow from the right gastric and right gastro-epiploic arteries. The nutrition of the tissues at the site of the anastomosis high in the apex of the fundus depends primarily upon the preservation of a continuous arcade of vessels through the gastro-epiploics on the greater curvature side and the anastomoses between the branches of the right and left gastric arteries on the lesser curvature side. Of utmost importance, likewise, is the maintenance of the integrity of the intercommunicating vessels within the wall of the stomach which connect these two primary sources of supply. It is these vessels upon which the viability of the gastric wall at the site of the anastomosis is completely dependent. It is necessary, therefore, in handling the stomach throughout the entire operation to exert every effort to avoid trauma to its wall and to the vessels which course within it. A tear produced by a forcep or a clamp or an hematoma resulting from careless handling might be the determining factor in the occurrence of an unfavorable outcome.

(B) Preservation of an adequate blood supply to the site of anastomosis on the esophageal side depends upon a knowledge of the segmental nature of its blood supply. If the anastomosis can be made just below the aortic arch,

the integrity of the small arteries arising from the arch and from the bronchial arteries insures adequate nutrition of the tissues at the cut-end of the esophagus. If, however, it becomes necessary because of the high extent of the tumor to dissect the esophagus further and to pull it up from behind the aortic arch, the benefit of these vessels is sacrificed and the only remaining blood supply to the esophagus is that which descends from the inferior thyroid artery. It follows, therefore, that when the esophagus has been pulled out from behind the aortic arch it must always be divided at a high level within the chest in order to avoid necrosis of its cut-end at the anastomosis site. This must be kept in mind when there appears to be a relatively long, uninvolved portion above the tumor after the dissection has been carried out. Although it is more difficult from a technical standpoint to divide the esophagus high under these conditions, it may mean the difference between success and failure in the outcome of the operation.

(3) *Management of the Thoracic Duct:* If, as in the majority of cases, it is necessary to carry the dissection above the aortic arch, the thoracic duct may be encountered where it crosses the esophagus to assume a more anterior position behind the subclavian artery. If the growth lies in this region, the duct may be adherent to it or actually invaded, making it necessary to excise a segment. In some cases, after the esophagus has been dissected out, the thoracic duct may be seen loosely draped across the empty space left in the superior mediastinum. Under such conditions there is danger that the thinned-out or actually traumatized wall of the duct will result in leakage of chyle. In either case, it is important to tie the thoracic duct to prevent such an occurrence.

In the 32 cases reported, the thoracic duct was tied and divided in three, with no ill effects. In a fourth case, the duct was injured but through an oversight it was not tied. This patient died subsequently as the result of a persistent chylous hydrothorax.

(4) *Avoidance of Stricture at the Anastomosis:* Prompt and accurate healing of the layers of the anastomosis, especially the mucosa, is necessary to avoid extensive cicatrization and the resultant stenosis which follows the contraction of scar tissue. To accomplish this, all unnecessary trauma to the edges used in the anastomosis must be avoided. Measures which should be adopted to minimize the amount of trauma to these edges are (a) avoidance of the use of crushing clamps on either the gastric or esophageal side; (b) the utilization of knife and scissors to cut the esophagus and stomach instead of the cautery or a chemical caustic, such as carbolic acid on a knife; and (c) the use of interrupted fine sutures instead of running sutures which tend to constrict uniformly the edges of the entire circumference of the anastomosis and, thus, produce necrosis which results in delayed healing. The utilization of a circular opening in the stomach wall for the anastomosis may be of some further importance.

## EXPERIENCE WITH CARCINOMA OF THE MIDTHORACIC ESOPHAGUS IN 66 CASES SEEN DURING 1944 AND 1945

The first resection and high intrathoracic esophagogastric anastomosis above the aortic arch for carcinoma of the midthoracic esophagus at the Massachusetts General Hospital was performed early in 1944. Since then, this procedure has been used in these cases in place of the Torek operation.

*Operability:* During 1944 and 1945, 66 cases of carcinoma of the middle half of the esophagus were observed (Table III). Of these, 25 were considered to be inoperable because of their extremely poor general condition.

TABLE III

CARCINOMA OF THE MIDTHORACIC ESOPHAGUS

*Operability—1944 and 1945*

| | No. | Per Cent |
|---|---|---|
| Total cases seen | 66 | |
| Cases operated upon | 41 | 62.1 |
| Resection performed | 32 | 48.5 |
| Total cases operated upon | 41 | |
| Exploration only | 9 | 22.0 |
| Resection with anastomosis | 32 | 78.0 |

The majority of these died within a few weeks of the time they were first seen at this hospital. Forty-one patients, however, were operated upon after adequate, often prolonged preoperative preparation to improve their nutritional status. Of this number, nine were found to have tumors which could not be removed. In the remaining 32 cases a radical resection followed by high intrathoracic esophagogastric anastomosis was performed. Thus, of the total number of patients seen 62 per cent were operated upon, and it was possible to perform a radical operation in 48.5 per cent. Of the total number of patients operated upon, 78 per cent were given the benefit of resection (Table III). This high resectability is the result of a policy in the management of these cases which is calculated to provide a worth while degree of palliation for as many patients as possible by always removing the growth unless there is a serious technical obstacle which prevents it.

*Inoperable Cases Explored:* In nine cases it was impossible to remove the growth because of extensive local fixation and invasion of important structures, such as the aorta, the bronchus, or the inferior pulmonary vein. Eight of these patients made an uncomplicated recovery following the exploratory thoracotomy and left the hospital. One died of widespread lymphatic invasion of both lungs while still in the hospital. The majority of the remaining patients died within a few months after exploration.

*Cases of Resection Followed by Anastomosis.—Age of Patients:* Before taking up the consideration of the results of resection, it is important to bear in mind that a very large percentage of the patients upon whom a resection and high anastomosis was performed were old. Table IV illustrates the age distribution. It is noteworthy that over one-half of the patients (19 in all) were 65 years of age or older. Five of these were 70 or more.

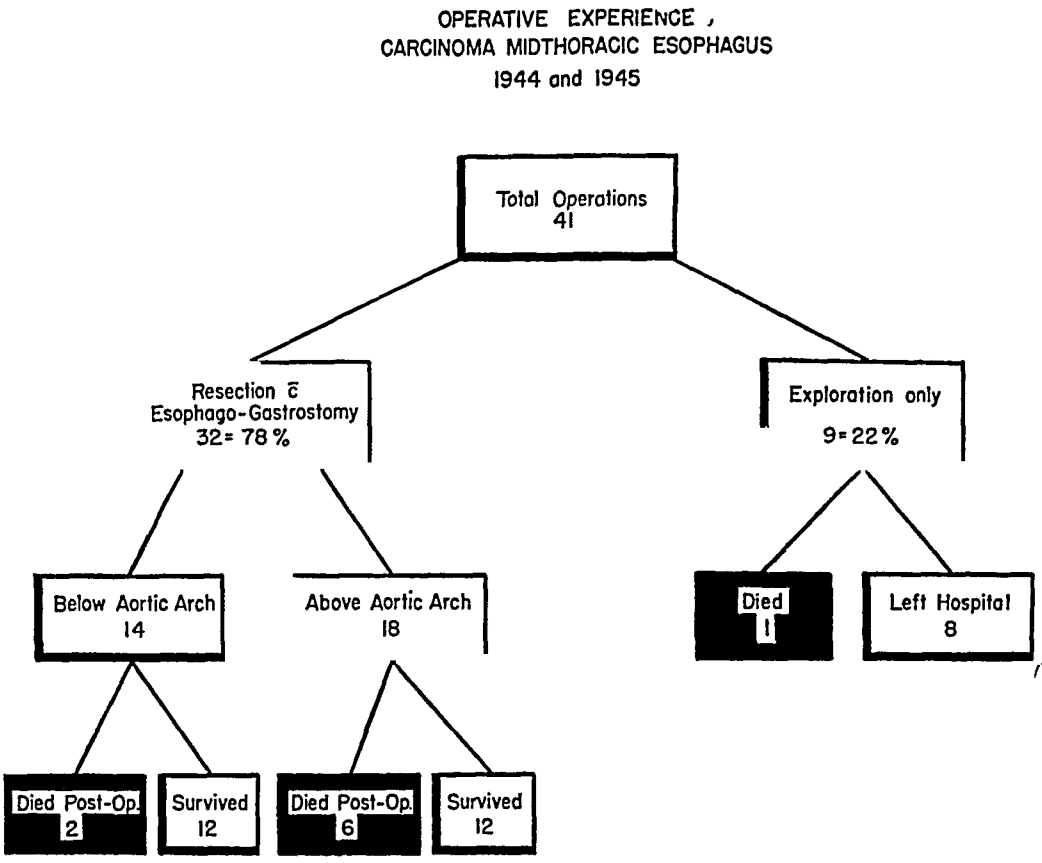



Chart 2.

*Distribution According to the Level of Anastomosis:* Of the 32 patients who had an esophagectomy carried out, it was possible to perform the anastomosis just below the aortic arch in 14. But in the remaining 18 cases it was necessary to dissect the esophagus from behind the aortic arch and perform the anastomosis above the arch (Chart 2). The importance of this is reflected in an analysis of the frequency of complications and postoperative deaths.

TABLE IV

AGE DISTRIBUTION OF RESECTION CASES

| | |
|---|---|
| 40–45 | 1 |
| 45–50 | 2 |
| 50–55 | 2 |
| 55–60 | 3 |
| 60–65 | 5 |
| 65–70 | 14 |
| 70, or over | 5 |

For example, of the 13 cases in which complications developed, ten were in the group where the anastomosis was performed above the aortic arch and only three were in the group where the anastomosis was carried out just below the arch. Likewise, the number of postoperative deaths was much larger in

TABLE V

CARCINOMA OF THE MIDTHORACIC ESOPHAGUS (32 CASES)

*Complications Following Resection with High Esophagogastric Anastomosis*

| Complication | Subaortic Anastomosis | Supra-aortic Anastomosis | Total |
|---|---|---|---|
| Cardiac Disorders: | | | |
| Congestive failure | 0 | 4 | 4 |
| Myocardial infarction | 1 | 0 | 1 |
| | 1 | 4 | 5 |
| Manifestations of Infection: | | | |
| Wound sepsis | 0 | 1 | 1 |
| Empyema | 0 | 1 | 1 |
| Mediastinitis | 0 | 1 | 1 |
| | 0 | 3 | 3 |
| Chylous hydrothorax | 0 | 2 | 2 |
| Pulmonary embolus (sublethal) | 1 | 0 | 1 |
| Pulmonary atelectasis | 1 | 0 | 1 |
| Surgical shock | 0 | 1 | 1 |
| Total | 3 | 10 | 13 |

the former group than in the latter (six cases as compared with two cases). The explanation of these observations lies in an appreciation of the fact that the higher the lesion is, the greater the amount of dissection required and the more the trauma which results. The supra-aortic anastomosis group, in addition to the hazards of a larger amount of dissection in the mediastinum close to the heart and other vital structures there, is subjected to a longer procedure and to the hazards of a more difficult anastomosis.

*Analysis of the Complications and Causes of Death Occurring after Resection:* Tables IV and V enumerate the complications and causes of death which

TABLE VI

CARCINOMA OF THE MIDTHORACIC ESOPHAGUS (32 CASES)

*Causes of Death Following Resection with High Esophagogastric Anastomosis*

| Cause | Subaortic Anastomosis | Supra-aortic Anastomosis | Total |
|---|---|---|---|
| Cardiac Disorders: | | | |
| Congestive failure | 0 | 3 | 3 |
| Myocardial infarction | 1 | 0 | 1 |
| | 1 | 3 | 4 |
| Sepsis: | | | |
| Empyema | 0 | 1 | 1 |
| Mediastinitis | 0 | 1 | 1 |
| | 0 | 2 | 2 |
| Chylous hydrothorax | 0 | 1 | 1 |
| Pulmonary atelectasis | 1 | 0 | 1 |
| Total | 2 | 6 | 8 (25%) |

developed in the group of 32 patients who were subjected to resection and high intrathoracic esophagogastric anastomosis.

*Cardiac Disorders:* As might be expected, the greatest incidence of cardiac disorders was in the group of patients who had a supra-aortic arch anastomosis. Four of this group developed congestive failure and three of these died. Myocardial infarction developed in one patient of the subaortic anastomosis group. This patient died.

*Manifestations of Infection:* Only three patients of the entire series developed sepsis. In all three cases the difficulty arose in the group of patients

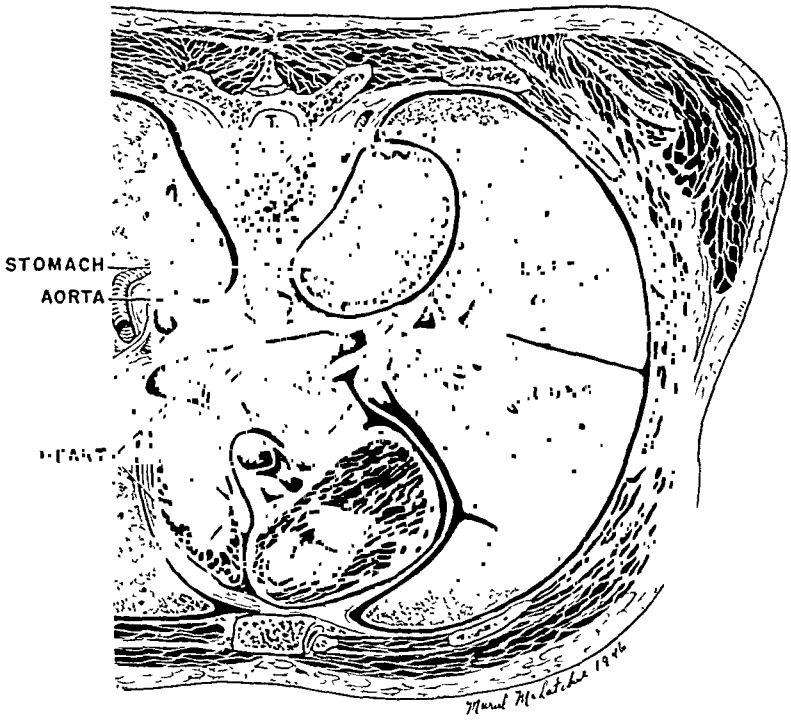



FIG. 4.—Cross-sectional relations of viscera at level of thoracic vertebra VII, showing stomach behind the hilum of the lung.

who were operated upon in 1944, before penicillin was available for civilian use. Since penicillin has been used routinely as a prophylactic measure, there have been no manifestations of infection of any kind in 29 consecutive cases. *Major wound sepsis* occurred in one case. The organism was *Staphylococcus aureus.* A special grant of penicillin was obtained, as a result of which the infection was brought under control. *Empyema* developed in one case. Penicillin could not be obtained. Drainage was established by rib resection but the patient, who was elderly and in poor general condition, died. The third case of infection was a severe and ultimately fatal *mediastinitis* resulting from accidental perforation of the growth during the process of dissection behind the aortic arch in a case which was practically inoperable.

*Chylous hydrothorax* developed in two cases. Both occurred in the right side of the chest. In each case a portion of the right mediastinal pleural reflexion had been removed. In one, the accumulation was gradual and never very large in amount. It developed several weeks after the operation and was probably the result of involvement of the thoracic duct by carcinoma arising in lymph node metastases within the mediastinum. The patient left the hospital and died a few months later of metastatic disease. This case appears in Table IV but not in Table V. In the other case the chylous effusion developed during the first few days after the operation and resulted in the death of the patient. It was in this case that the injury to the thoracic duct was observed at operation, but through an oversight the duct was not tied. In both these cases a supra-aortic anastomosis was performed.

A *sublethal pulmonary embolus* occurred in one patient. Immediate bilateral superficial femoral vein ligation was resorted to, and no subsequent emboli developed. The patient recovered and has had no difficulty with his legs since the ligation was performed.

*Pulmonary atelectasis* developed on the left side in one elderly woman who had an emphysematous chest with a marked kyphosis. Bronchoscopic aspiration failed to produce permanent relief and the patient died on her 4th postoperative day.

*Transitory surgical shock* occurred in one patient. It responded to the usual methods of treatment.

## SUMMARY

The inadequacy of the Torek procedure from the standpoint both of cancer cure and of palliation in unfavorable cases has made it necessary to abandon the procedure after a trial of 14 cases.

Recent experience has demonstrated the superiority, in each respect, of resection followed by a high intrathoracic esophagogastric anastomosis placed either just below or actually above the aortic arch. This technic is applicable in any case when the growth is located in the middle half of the esophagus, even in cases where the tumor extends upwards behind the arch.

A report of experience in the use of this procedure in 32 cases of carcinoma of the midthoracic portion of the esophagus is given. The technic of the procedure and the complications and causes of death are discussed.

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[1] Torek, F.: The First Successful Resection of the Thoracic Portion of the Esophagus. J. A. M. A., 60, 1533, 1913.

[2] Sweet, R. H.: Surgical Management of Carcinoma of the Midthoracic Esophagus: Preliminary Report. N. E. J. Med., 233, 1, 1945.

DISCUSSION.—DR. HAROLD W. WOOKEY, Toronto, Ont.: I have been very much interested in Doctor Sweet's paper on the treatment of cancer of the midthoracic esophagus. A good many of us have operated upon such cases using some modification of the original Torek procedure, but there is no question that patients who try to exist with an esophageal fistula and a gastrostomy are in a most unhappy state. Conse-

quently, it would seem that some method of reconstruction of the esophagus is an essential part of treatment.

Many such methods have been described. The simplest of these is a reconstruction by means of a tube of skin in front of the sternum. This method has necessitated multiple operations, tedious not only for the patient but for the surgeon. It would seem, therefore, that the intrathoracic reconstruction offers many great advantages. In cases in which the growth occurs low down in the esophagus, this procedure may be relatively simple. However, in cases of midthoracic esophageal cancer such growths lie at least in part behind the arch of the aorta, and separation of the tumor when approached from the left side has to be done blindly. One should remember the relations of the vena azygos major, which may be closely adherent to the tumor and, in one case in my experience, an injury of this vessel led to an uncontrollable hemorrhage.

The procedure of bringing the upper end of the esophagus over the arch of the aorta into the left side of the chest enables one to do an anastomosis which would be otherwise impossible. I am showing a slide illustrating such a case in which this has been carried out successfully and the patient has done very well. However, it sometimes happens that the growth is just too high in the esophagus for an intrathoracic anastomosis and too low to be reached through the neck. In such a case I have found it necessary to completely remove the thoracic esophagus and to bring out the upper end in the neck. I should like to refer to the use of a skin tube in reconstruction of the esophagus and am showing a slide of a roentgenogram taken of such a patient on swallowing barium. This slide shows the barium passing down a skin tube in front of the sternum and emptying freely into the stomach. This man was operated upon eight years ago and has remained perfectly well ever since. The skin tube has functioned perfectly and has never required any special care.

One sometimes has difficulty with a fistula developing along the line of the skin tube and this fistula may be difficult to close. I am showing a photograph of a patient in which this occurred. Operation was carried out three years ago. By means of a specially devised rubber obturator the fistula has been closed and the patient has been able to take normal food, and has remained perfectly well.

The future, no doubt, will decide whether the intrathoracic reconstruction will eventually replace other methods. This will depend on the relative mortality rates and also on the function of the intrathoracic anastomosis over a period of years.

DR. FREDERICK L. REICHERT, San Francisco, Calif.: I should like to mention that our resident, Doctor Menke, was able to bring up the stomach and anastomose it above the arch of the aorta because he did what Dr. J. M. T. Finney, Sr., demonstrated—mobilization of the duodenum. Certainly, if you ligate the proper vessels of the stomach and mobilize the duodenum adequately you can bring it up above the arch successfully. I mention that as a means of doing an esophageal gastric anastomosis without a plastic loop of the jejunum.

DR. RICHARD H. SWEET, Boston, Mass. (closing): I wish to thank Doctor Wookey and Doctor Reichert for their discussions. I am eager to discuss this problem with Doctor Wookey because there is one region of the esophagus which remains to be conquered—that which lies above the aortic arch and behind the jugular notch. Doctor Reichert's comment about the advantage of mobilizing the duodenum is proper. This was described several years ago by Doctor Phemister and has been practiced by many. There has been considerable doubt in the minds of some surgeons about the advisability of dividing the left gastric vessels. Of course, it is essential in this operation. I have done it in many cases. By so doing we are better able to remove lymph node metastases, and, with care, one can preserve the blood supply so that the apex of the fundus can be brought to the top of the thorax.

# BRONCHIOGENIC CARCINOMA*

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RAPID ADVANCES have been made in the technic of surgical resection for the eradication of primary pulmonary cancer since Graham reported the first successful total pneumonectomy for carcinoma in 1933. Thereafter a commendable optimism began to appear, with published reports of successful cases, or series of cases. To date, however, too few surgeons have indicated the background of case material from which their occasional therapeutic successes have been derived. Considered in this light, the comprehensive picture of therapy for bronchiogenic carcinoma is still a disappointing one and constitutes a challenge to further efforts.

It is the author's purpose to relate his own experience with a consecutive series of 100 primary pulmonary cancers seen within a five-year period, ending December 1943, at the New Haven Hospital, which is a general hospital of about 500 beds.

VITAL STATISTICS.—There were 82 male and 18 female patients, a ratio of 4.5 to 1. Ninety-nine were white and one negro, an expected racial distribution since the State of Connecticut has a negro population of 1.9 per cent, according to the 1940 census. The average age of all patients was 54.8 years. In this decade occurs the peak incidence of nearly all visceral cancer. The youngest patient was 22 years of age. There were five cases in the fourth decade, 21 in the fifth, 41 in the sixth, 28 in the seventh, and four patients were older than 70.

SYMPTOMATOLOGY.—The first observed symptom was usually cough, pain in the chest, or a grippe-like "cold." Sixty per cent of the cases began with one of these three complaints. Six had early dyspnea. Only four patients noted hemoptysis or bloody sputum as an *early* complaint. Three had an acutely pneumonic onset. Nine patients had vague general complaints of weakness and weight loss, and 14 had initial symptoms frankly related to metastases or extensions of tumor beyond the lung.

The average duration of symptoms prior to hospital admission was 6.7 months in 98 cases; two cases were unable to evaluate the time of onset. The inoperable cases had an exactly similar average duration. The presumably operable group, which was subjected to surgical exploration, had a slightly longer duration of symptoms, rather than a shorter one.

LOCATION OF THE PRIMARY LESION.—The right lung was affected 51 times and the left 47. This is approximately the normal ratio of the two lungs in

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terms of volume and respiratory capacity. The upper lobes, together with the stem bronchi above the upper lobe orifice, were involved in 69 per cent. In one bilateral lymphatic lesion and one essentially mediastinal case, the primary focus defied localization.

TABLE I

BRONCHIOGENIC CARCINOMA

*Symptoms*

First Symptom:

| | | | | | |
|---|---|---|---|---|---|
| Cough | 27 | Bloody sputum | 4 | Hoarseness | 1 |
| Pain in chest | 21 | "Pneumonia" | 3 | "Indigestion" | 1 |
| "Cold" or "grippe" | 12 | Headache | 2 | Wheeze | 1 |
| Weight loss and weakness | 9 | Pain in back | 2 | Not reported | 3 |
| Dyspnea | 6 | Pain in abdomen | 2 | | |
| Pain in shoulder | 5 | Dysphagia | 1 | Total | 100 |

Average duration of symptoms prior to admission:

| | |
|---|---|
| Entire group (98 of 100 cases reporting) | 6.7 months |
| Inoperable (68 cases) | 6.7 months |
| Presumably operable and explored (30 of 32 reporting) | 6.8 months |
| Resected group (12 cases) | 7.2 months |

TABLE II

BRONCHIOGENIC CARCINOMA

*Location*

| | Right | Left | Total | |
|---|---|---|---|---|
| Proximal or diffuse | 3 | 10 | 13 | Proximal |
| Upper lobe | 28 | 28 | 56 | Upper |
| Lower lobe | 18 | 9 | 27 | Lower |
| Middle lobe | 2 | — | 2 | Middle |
| | 51 | 47 | 98 | |

| | |
|---|---|
| Bilateral lymphatic | 1 |
| Mediastinal | 1 |
| Total | 100 |

TISSUE DIAGNOSIS.—Positive tissue diagnosis was obtained in 82 cases, 77 in the living and five at autopsy of terminal cases. In the remaining 18 no tissue diagnosis was made, either because various methods failed, or because the patient refused the indicated procedures. In this group the clinical course was typical and all 18 subsequently died. In 29 the verification of metastases by biopsy gave simultaneously a tissue diagnosis, and a determination of inoperability.

Thoracoscopy proved itself of practical value in only two cases. Where a massive effusion was present, a microscopic examination of sediment from the fluid was easier and more frequently positive.

It is noteworthy that in 20 cases of 32 explored, operation was approached without a positive tissue biopsy, and with only a presumptive clinical diagnosis. In 10 of the 12 resections this also proved to be the case. If any support

is needed for the concept of exploratory thoracotomy in doubtful lesions, it will be found in these facts.

Needle biopsy of the lung was used successfully in five cases. Three of these were obviously inoperable; the other two were explored and found inoperable. In this clinic needle biopsy has been reserved for inoperable lesions where bronchoscopy, lymph node biopsy or other technics fail, and verification is desired before radiation therapy is begun. A negative needle biopsy has not been considered conclusive in any case.

Histologically, the tumors were classified as squamous or epidermoid (28); adenocarcinoma (11); or anaplastic (35). In eight cases, the type of tumor was not classified except as bronchiogenic carcinoma. In the squamous and anaplastic groups, the expected sex ratio of five or six to one was maintained. In the adenocarcinoma group the sexes were evenly represented. All of the cases under 40 years of age in which the type was specified were adenocarcinoma. These considerations suggest a different etiologic background, perhaps in congenital lesions or adenomata for the adenocarcinoma type.

TABLE III

BRONCHIOGENIC CARCINOMA

*Tissue Diagnosis*

| | | |
|---|---|---|
| Negative | | 18 |
| Positive | | 82 |
| At autopsy | 5 | |
| In living patient | 77 | |
| | | 100 |
| Method by which first made: | | |
| Bronchoscopy | | 28 |
| Lymph node biopsy | | 10 |
| Thoracotomy and biopsy | | 10 |
| Resection of lung | | 10 |
| Sedimentation of pleural fluid | | 5 |
| Needling of lung | | 5 |
| Thoracoscopy | | 2 |
| Biopsy of metastases | | 7 |
| (CNS 2, skin 1, thyroid 1, bone 2) | | |
| | | 77 |

THERAPY STATUS.—Sixty-five patients were found to be inoperable when first seen, and three refused treatment. Of the 65, 36 were proven by biopsy of metastases, or by involvement of important nerves; in three, the tumor was present at the tracheal carina or invading the trachea. In 18, presumptive evidence of inoperability, such as roentgenologic or bronchoscopic evidence of marked mediastinal distortion, was considered sufficient grounds for refusing exploration. Seven patients were moribund or with other lethal conditions. One patient had had radon treatment elsewhere: there was no bronchoscopic or roentgenographic trace of the original lesion, but he died four months subsequently of metastases.

Surgical exploration was carried out in 32 cases (one in another hospital). Twenty of these were found to have extensions to the hilar mediastinum (12 cases), to remote mediastinal nodes (2 cases), or dissemination to the

parietal pleura (6 cases). *Local* extension to the parietal pleura was not considered a contraindication to resection, a block resection of the locally involved area being performed in several cases.

Of the 12 resections, ten were total pneumonectomies and two total upper lobectomies. In the group of resections, ten were considered to be complicated cases. One case was complicated by putrid abscess. Three had local parietal pleural extension. One had tuberculous hilar nodes; one an obstructive pneumonitis with pneumococcal empyema. One case had massive pleural effusion

TABLE IV

BRONCHIOGENIC CARCINOMA

*Therapy Status*

| | |
|---|---|
| Inoperable | 65 |
| Refused treatment | 3 |
| Presumed operable and explored | 32 |
| Not resectable | 20 |
| Resected | 12 |
| Pneumonectomy, total | 10 |
| Lobectomy, total | 2 |
| Total | 100 |

TABLE V

BRONCHIOGENIC CARCINOMA

*Reasons for Inoperable Status*

| | | | |
|---|---|---|---|
| Metastases, proven to: | | Metastases or extension, *presumed* to: | |
| Regional nodes | 10 | Mediastinum | 14 |
| Pleura | 7 | (X-ray findings | 8) |
| Bone | 7 | (Bronchoscopic distortion | 6) |
| Mediastinum | 5 | Other lung (x-ray) | 2 |
| (Recurrent nerve paralysis | 2) | Pleura (effusion) | 1 |
| (Horner's syndrome | 1) | Adrenals (masses) | 1 |
| (Phrenic nerve paralysis | 1) | | |
| (Vena cava obstruction | 1) | Subtotal | 18 |
| Central nervous system | 2 | | |
| Chest wall | 1 | | |
| Esophagus | 1 | | |
| Skin | 1 | | |
| Thyroid | 1 | | |
| Trachea | 1 | | |
| Subtotal | 36 | | |

| | |
|---|---|
| Terminal state or lethal complications | 7 |
| Proximity to trachea by bronchoscopy | 3 |
| Previous radon treatment | 1 |
| Refused treatment | 3 |
| Total | 68 |

without gross pleural tumor involvement. Two had hilar (intertracheal) nodes invaded by tumor. One was suspected of contralateral metastases, proven by subsequent developments. Only two were considered to be entirely free of complications.

No patient was refused surgery because of age alone. The oldest resection was at age 68. The average age of the resected cases was 54.0, as compared with 54.8 for the entire series.

RESULTS OF TREATMENT.—In 38 cases which received only diagnostic and symptomatic care, the briefest life-span after diagnostic admission to this hospital was one month and the longest 36 months; the average was 5.0 months.

Twenty-nine cases received high voltage roentgenotherapy, radon implantation, or both. All of these are dead; the shortest life-space was two months and the longest 33. The average duration of life in this group was 7.4 months, an increase of doubtful significance over the untreated cases. However, in this treated group there was a very significant palliation in the form of pain relief, decrease of dyspnea, improved aeration and bronchial drainage, as well as psychotherapeutic benefit.

In the 20 cases submitted to unsuccessful exploration there were no operative or hospital deaths. Nine of these had no subsequent roentgen ray treatment, and the average life-span was 8.0 months. Eleven subsequently treated by roentgen ray lived an average of 11.8 months. This difference is not statistically significant.

TABLE VI

BRONCHIOGENIC CARCINOMA

*Present Status*

DEAD—96

Duration of life after date of first admission

| | Cases | Mean | Extremes | "t" | "P" |
|---|---|---|---|---|---|
| No special treatment | 38 | 5.0 months | 1—36/ | 1.56 | 0.15 |
| Roentgen or radon therapy | 29 | 7.4 months | 2—33/ | | |
| Exploratory thoracotomy | 9 | 8.0 months | 2—26/ | 1.09 | 0.3 |
| Exploration and roentgenray | 11 | 11.8 months | 6—28/ | | |
| Pneumonectomy: Hospital deaths | 3 | 1.3 months | 0— 2 | | |
| Later deaths | 6 | 12.3 months | 3—26 | | |

LIVING—4

| | |
|---|---|
| Pneumonectomy | 2 (1, 5.5 years; 1, 4 years) |
| Lobectomy | 1 (2 years and 3 months) |
| Roentgenotherapy | 1 (3 years and 4 months |

Three patients died in the hospital following total pneumonectomy (30% of the ten total pneumonectomies, 25% of the 12 resections). In summary, one patient aged 60, died 12 days postoperatively of aortic thrombosis and cardiovascular failure due to arteriosclerosis. One patient, aged 65, died with bronchial fistula and empyema at six weeks. One, age 53, succumbed with metastases while still in the hospital, two months after resection.

Six cases successfully submitted to resection have died subsequently of metastases at intervals ranging from three to 26 months postoperatively; the average survival was 12.3 months.

Four patients are living. One pneumonectomy case survives 5.5 years after resection, which included a block resection of the involved chest wall; the microscopic diagnosis was squamous cell carcinoma. The patient, a female Negro, then age 46, has recently recovered from pneumonia of the remaining right lung and is well. Another pneumonectomy case survives in good health 4.5 years after one-stage resection of the right lung for squamous cell carci-

noma in the presence of an encapsulated pneumococcal empyema; the latter was sterilized by sulfonamide chemotherapy. His attained age is 68, and he operates his own farm. One lobectomy case, age 70, is living without evidence of disease at two years and six months. The pathologic diagnosis was squamous cell carcinoma. One patient with anaplastic carcinoma in the mediastinum is living and working three and one-half years after roentgen ray treatment. He is the only radiation treatment case in which a strikingly lasting effect has been obtained. It is to be emphasized that two of the three surviving resections were complicated cases. All three were squamous cell tumors.

In addition, two patients with solitary metastases of carcinoma, from uterus and urinary tract, respectively, were treated by pneumonectomy with survivals of 24 and five months, respectively. They are not included in the statistical summary.

## SUMMARY

1. An unselected series of 100 primary bronchiogenic carcinoma cases, which were seen in a general hospital service, has been analyzed statistically.

2. Sixty-five patients were considered hopelessly advanced and found inoperable when first admitted. Three refused treatment.

3. Surgical exploration was performed in 32 cases. No positive tissue diagnosis was available in 20 of these cases despite various diagnostic studies. Twenty of the 32 patients were found not suitable for resection at the time of exploration. There was no hospital mortality in this group.

4. Twelve patients were submitted to surgical resection (ten pneumonectomy, two lobectomy), with a hospital mortality of 25 per cent.

5. Three patients are surviving 2.5 to 5.5 years after successful resection. All had squamous cell carcinoma. They are now clinically well.

6. One patient survives and is working 3.5 years after radiation therapy.

7. Radiation therapy increased the average life expectancy from 5.0 months in the untreated group to 8.6 months in the group which was treated by radiation, with or without surgical exploration. This difference of 3.6 months does not have statistical significance.

DISCUSSION.—DR. EVARTS A. GRAHAM, St. Louis, Mo.: I am glad that Doctor Lindskog has reported his results. It is desirable that everyone who is having experience with bronchiogenic carcinoma should present his results because it is still necessary to indulge in a campaign of education of the medical profession about this disease. I do not share the pessimism which some others have. The only aspect that I am pessimistic about is the fact that in most cases the condition is not recognized early enough to do something for the patient. The fault is partly the patient's own, because he neglects to see his doctor. I am sorry to say, however, that the larger fault is with the medical profession who fail too often even to think of the possibility of the condition.

In the last three years (1943, 1944, 1945) 221 patients have been admitted to the Barnes Hospital with bronchiogenic carcinoma. Of this number, 109 patients (49 per cent) were considered inoperable on the basis of the clinical examination. Although 112 were subjected to exploratory operation, in only 39 cases (18 per cent) was it possible to remove the lung with a reasonable chance of curing the patient. These figures show

why it seems necessary to educate both the public and the medical profession in the early signs and symptoms. The diagnosis in most cases is easy. In our experience a positive bronchoscopic diagnosis can be made in about 70 per cent of the cases. Even in the others the clinical and roentgenographic evidence is sufficiently characteristic to make the diagnosis almost certain.

There is certainly too much pessimism about the end-results of operation for bronchiogenic carcinoma. Although cancer is always a serious disease and the sudden removal of an entire lung is necessarily a severe physiologic jolt to one whose cardiovascular system is not entirely normal, nevertheless the results of the operation are very encouraging. The first patient who had a successful total pneumonectomy for this condition is alive and well 13 years later. I have six patients who are alive and well more than seven years after operation. I think if patients can be obtained in larger numbers in an operable stage it will be possible in another decade for someone to report before this Association 50 to 60 per cent of five-year cures.

DR. ALTON OCHSNER, New Orleans, La.: I would like to emphasize a point referred to by Doctor Lindskog, that is the necessity for operating upon more of these people. I was astounded by the statements of Doctor Graham and Doctor Lindskog that so few are operable. We have had 267 primary carcinomas in which we were able to do a resection in 103 cases, an incidence of 34.4 per cent; 28 per cent were refused operation and one refused operation. I feel that inoperability means metastases. I think palliative resection is justifiable. Of 166 operated upon, 103 were resected (62 per cent). Not all are well by any means, but I think we are justified in doing palliative resection if we can do it safely. I have one patient alive five years after resection of a tumor which had invaded the mediastinum, in which there was recurrent nerve paralysis. I am sure he is going to die and I am sure he has cancer, but he is free from pain. So I would like to make a plea for resection for palliative reasons.

DR. CARL EGGERS, New York City: I would like to add a small list to this imposing group. I am not giving the total number of cases seen, which is large, but we have explored 35 patients. We performed lobectomy in one and complete pneumonectomy in 15. I agree with Doctor Ochsner that one should not hesitate to explore, because some cases that look discouraging may turn out to be operable. The results in our cases are as follows: Eight patients have died since removal of the tumor, two or three postoperatively, the others anywhere from a few weeks to two and one-half years later, all of recurrence; seven patients are living, one seven years, one four years, one three years, one two years, and the other three cases something over a year. The interesting thing is that the patient living longest is one who had lymph node involvement. This indicates that in cancer of the lung one has to use the same radical procedure as in cancer of other organs. All these patients who are living have returned to their usual occupation—work or golf—and apparently are entirely well.

I should like to show some slides which illustrate the rate of growth of some lung cancers and also stress the importance of paying attention to small tumors. The first patient had a routine chest examination made at the medical department of one of the life insurance companies. A little shadow was found in the upper lung. Bronchoscopy was advised but refused because of the absence of symptoms. The next year, on examination, the tumor had somewhat enlarged, but bronchoscopy was again refused. Later in the year the patient began to have symptoms, and roentgenograms showed the tumor still larger. When seen at the hospital, a planogram showed not only the tumor but also a large lymph node in the hilum. A pneumonectomy was performed and the patient recovered and returned to her work. About two years later she developed metastasis and succumbed. Had she been operated upon earlier she might have been cured.

The second case is the relative of a physician who was visiting in his home. During conversation he heard her wheezing, whereupon he took a roentgenogram of the chest and found atelectasis of one lung. An interesting feature of this case is that on looking over a roentgenogram taken four years before, a shadow is visible at the site of the present atelectasis. A diagnosis of carcinoma was made and she had a pneumonectomy performed, with recovery. There is reason to believe that this is one of the slow-growing carcinomas which took four years to reach a size blocking the bronchus. It should offer a favorable prognosis.

DR. GUSTAF E. LINDSKOG, New Haven, Conn. (closing): I wish to thank Doctor Graham, Doctor Ochsner and Doctor Eggers for their comments. I did not mean to leave a note of complete pessimism, but I do want to emphasize that our series is typical of the case material we are up against in general hospitals at the present time; even though in the state of Connecticut, I believe, we have a good educational program against cancer. While I was in the Service another surgeon had charge of our chest service, and we know his figures are not going to vary greatly from this series.

I also have operated upon a group which might be considered palliative. Ten of the 12 resections were complicated pathologically. One case surviving five and a half years had an involvement of the pleura locally by extension of the tumor. A second case had an empyema of pneumococcal type complicating obstruction by the tumor, and this patient was operated upon in a single stage, with primary closure. The third living patient had no complications.

In the roentgen ray treatment group only one patient is living with the disease, at three and a half years. The proper management of this disease depends in part on education of the public, but also on education of the practitioner, who must be made responsible for initiating the diagnostic program.

# PALLIATIVE GASTRECTOMY IN SELECTED CASES OF GASTRIC ULCER*

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CHRONIC BENIGN ULCERS high on the lesser curvature of the stomach and those juxta-esophageal in position have always presented technical problems in their surgical management. A multiplicity of procedures has been advocated. At first, these operations were designed to relieve the gastric retention secondary to a reflex pylorospasm. However, gastrojejunostomy, usually without the local excision of the lesion, even though it relieves the obstruction, has been found to be an unreliable and ineffectual operation in most of these cases of gastric ulcer and occasionally a gastrojejunal ulcer develops. Gastro-enterostomy produces no permanent reduction in the degree of gastric acidity which evidently is more fundamental in the pathogenesis of ulcer than is the correction of motor disturbances. Pyloroplasties of various types which aim to eliminate the reflex spasm of the pyloric canal rarely effect a permanent healing of these high gastric lesions. A sleeve resection in this type of case is not only impractical but also fails to correct one of the basic factors responsible for the production of ulcer. Jejunostomy for ailmentation as a definitive procedure in gastric ulceration has been discarded. It still is indicated as a preliminary procedure[1] in those cases in which a massive ulceration adherent to neighboring organs precludes immediate gastric resection. At present, most surgeons have unequivocally accepted subtotal gastrectomy as the operation of choice in gastric ulcer. Not only is the ulcer-bearing area removed for careful histologic examination, but the resection of the pylorus and antrum eliminates the chemical phase of gastric secretion and causes an appreciable reduction in the acidity. Follow-up examinations of patients upon whom a subtotal gastrectomy has been performed for gastric ulcer have revealed uniformly satisfactory results. Chemical analysis of test meals in these patients have shown an achlorhydria in well over 95 per cent of these cases, and when a subtotal gastrectomy is performed for lesions at or above the reëntrant angle of the stomach in which not only the pylorus and antrum are resected but part of the fundus as well, an achlorhydria results in practically 100 per cent of the cases.[2] In the absence of gastric acidity, gastric and gastrojejunal ulcers apparently do not develop, and it is mainly for this reason that the operation of subtotal gastrectomy for gastric ulcer has been so incontrovertibly established. Unfortunately, however, a radical removal of juxta-esophageal lesions would entail a complete

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gastrectomy, an operation attended primarily by a high mortality rate, and, if the patient survives, by nutritional difficulties of a permanent nature. It is true that innumerable modifications embodying the principle of gastric resection have been done for ulcers high on the lesser curvature. The history and description of these various procedures have been excellently reviewed and thoroughly discussed.[3] These operations have as their goal the removal of the ulcer-bearing lesser curvature, leaving a patent esophagus and enough of the fundus to effect a gastro-enteric anastomosis, but, at best, they are technically difficult even in the hands of experts. What would be the result, then, if in these high-lying gastric lesions, presumably benign by all available clinical and laboratory criteria, an adequate subtotal gastrectomy could be performed below the lesion, leaving the ulcer *in situ? A priori,* an achlorhydria should result. Clinical experience has shown this to be true and has demonstrated that these ulcers not only heal in an anacid stomach, but do not recur.

Madelener,[4] in 1923, reported the first successful cases of high-lying gastric ulcers which completely disappeared following a simple pylorectomy followed by a Billroth-I anastomosis. Florcken[5] subsequently performed a subtotal gastrectomy of the Billroth-II type, distal to the ulcer, which he did not remove, and called the procedure "palliative gastric resection." Since then numerous European surgeons have reported their experiences with this procedure.[3] It must be stressed that it is applicable only in those cases in which the ulcer occupies the upper third of the stomach so that approximately one-half to two-thirds of the stomach distal to the lesion may be resected. This will naturally restrict the field of "palliative gastric resection" to (1) juxta-esophageal ulcers and peptic ulcers of the esophagus; (2) high lesser curvature ulcers; and (3) these penetrating ulcers situated on the posterior wall of the cardia in which the general physical condition of the patient does not warrant the operative trauma of a subtotal gastrectomy with the removal of the ulcer.

The operation is best performed under spinal anesthesia. The usual mid-epigastric incision is made from the ensiform cartilage to the umbilicus. The stomach is then carefully examined to determine the extent and nature of the lesion. The gastric lymph nodes and liver are palpated for evidences of metastases. If there is doubt as to the benign nature of the ulcer, the lesion may be visualized through a gastrotomy and, if necessary, a specimen removed for immediate pathologic examination.

The technic of palliative gastrectomy is similar to that employed for a retrograde subtotal gastrectomy. The right gastric vessels are ligated distal to the pylorus, and, at a point opposite, close to their origin, the right gastro-epiploic vessels are divided. The duodenum is then sectioned just distal to the pylorus, closed in layers, and buried against the head of the pancreas. The pyloric end of the stomach is reflected to the left and the gastrocolic omentum is divided. This gives an excellent exposure of the lesser omental sac, and any attachments of the posterior wall of the stomach to the pancreas.

The left gastro-epiploic vessels are divided at the point of proposed resection, and the left gastric artery is ligated distal to the ulcer. After this mobilization, one may determine whether it is more expedient to include the ulcer in the resection or simply perform a palliative gastrectomy. A DePetz clamp is then applied and the resection completed. Gastro-intestinal continuity is restored by an isoperistaltic terminolateral gastrojejunostomy of the Hofmeister type, made anterior to the colon. The abdominal incision is closed with interrupted buried steel wire.

It is granted that certain complications may follow a gastric ulcer which has been left *in situ*. In our experience, and those of others, these are fortunately rare.[3] It has been stated that the reduction of acidity decreases its bacteriocidal effect and that the infection ordinarily present in these callous ulcers may increase. Occasionally a profuse diarrhea, probably due to an enteritis secondary to a gastric anacidity may occur. Bleeding and perforation of the ulcer have been reported. Cicatrices incident to the healing of these high ulcers have caused esophageal stenoses but these yield to dilatation. Subsequent malignant degeneration of a previously benign ulcer is exceedingly rare, but one may diagnose a lesion as benign when in reality it is malignant. However, the results of a total gastric resection for a penetrating carcinomatous ulcer of the cardia are so poor that the error of performing a total gastrectomy for benign ulcer is decidedly worse than that of performing a palliative gastrectomy for a high-lying malignant ulcer.

During the past seven years subtotal gastrectomy was the only operative procedure employed in 53 consecutive ward patients suffering from gastric ulcer.[6] In eight of these cases a palliative gastrectomy was performed. This group consisted of patients over 50 years of age, and in poor general condition. Some had been recalcitrant to repeated courses of medical treatment. Others were suspected preoperatively of having malignant disease of the stomach and were explored soon after admission. Seven patients had normal or elevated free and combined acid figures in the Rehfuss test meal; low acid figures were obtained in one patient.

There was one postoperative death which occurred within 24 hours, and was apparently due to an acute coronary thrombosis.

The patients were personally interviewed and examined at frequent intervals in our Follow-up Clinic for periods ranging from 21 months to eight years (Table I). All have been relieved of gastric symptoms and have gained weight. Rehfuss test meals (specimens taken every 15 minutes during a two-hour period) disclosed the complete absence of free hydrochloric acid in every specimen. Most patients have had these tests repeated, with similar results. Repeated roentgenographic and gastroscopic studies have failed to disclose any pathology, except in Case 8, in which there was evidence of fibrous narrowing at the ulcer site (Fig. 3B). This patient died 21 months after operation from uremia and pneumonia; and autopsy disclosed a completely healed gastric ulcer.

It seems logical to assume that in selected cases of high-lying chronic

gastric ulcers, palliative gastrectomy produces a permanent gastric achlorhydria, with subsequent healing and disappearance of the ulcer which was left *in situ*. These patients have remained clinically free of symptoms, and gastroscopic and roentgenologic examination have failed to reveal any recurrence of either a gastric or a gastrojejunal ulcer. This operation has its place in the surgery of peptic ulcer and is indicated in benign lesions limited to the upper third of the stomach.

## CASE REPORTS

CASE 1.—H. Z., (No. 416481), a 55-year-old blacksmith, was readmitted, November 10, 1937, complaining of pain in the upper abdomen. He had originally been admitted to the hospital in January, 1937, at which time he gave a six-month history of epigastric pain partially relieved by food, weakness, and the loss of ten pounds in weight. The remainder of the history was noncontributory. Examination had been essentially negative. Roentgenologic examination had disclosed a penetrating ulcer on the lesser curvature well above the reëntrant angle. The patient had been treated medically, and after three and one-half weeks was asymptomatic and was discharged. The lesion had grown distinctly smaller, as seen roentgenographically. The patient was well for about a month, after which the pains recurred. During the month before readmission his symptoms had increased in severity, and food and medication no longer produced relief. He returned to the hospital for surgical therapy.

TABLE I

| Case No. | Age | Size in Cm. of Resected Specimen: Lesser Curvature | Size in Cm. of Resected Specimen: Greater Curvature | Preop. Acidity: Free | Preop. Acidity: Comb., | Postop. Acidity: Free | Postop. Acidity: Comb. | Follow-up Years and Months |
|---|---|---|---|---|---|---|---|---|
| 1 | 55 | 14 | 16 | 62 | 74 | 0 | 34 | 7 years, 0 months |
| 2 | 50 | 11 | 17 | 40 | 68 | 0 | 8 | 8 years, 3 months |
| 3 | 58 | 9 | 14 | 70 | 84 | | | Ceased 1 day, p.o. |
| 4 | 54 | 8 | 17 | 55 | 80 | 0 | 14 | 6 years, 7 months |
| 5 | 61 | 7 | 19 | 65 | 90 | 0 | 30 | 5 years, 4 months |
| 6 | 53 | 8 | 21 | 2 | 15 | 0 | 20 | 5 years, 2 months |
| 7 | 54 | 3 | 19 | 20 | 55 | 0 | 10 | 2 years, 3 months |
| 8 | 80 | 8 | 20 | 30 | 55 | 0 | 16 | 1 year, 9 months |

Examination disclosed an elderly male in moderately severe pain. His oral hygiene was extremely poor. Examination of the chest disclosed evidences of chronic bronchitis and emphysema. The heart sounds were distant. There was a faint systolic murmur at the apex. There was moderate peripheral arteriosclerosis. Blood pressure 160/90. The upper abdomen was tender. The liver edge was palpable 3 cm. below the costal margin. There was a left inguinal hernia present. The hemoglobin was 98 per cent. Blood chemistries were reported—urea 17 mg. per cent, sugar 100 mg. per cent, chlorides 450 mg. per cent, and $CO_2$ combining power 56.5 vol. per cent. Urine was negative. The Rehfuss test meal disclosed a free acid of 62, and a combined acid of 74 millimoles per cent.

It was felt that this patient was suffering from a deeply penetrating ulcer which was not responding satisfactorily to medical therapy, or possibly from an ulcerating

carcinoma. He had had an adequate trial of medical therapy both in the hospital and at home, with unsatisfactory results.

Accordingly, on November 13, 1937, the patient was explored under avertin-ethylene anesthesia. High up on the lesser curvature and posterior wall of the stomach was a hard indurated mass which invaded and was attached to the pancreas. The lesion was red and edematous and extended downward from the esophagus to about the reëntrant angle of the stomach. In the region of the duodenum there was evidence of an old ulcer with adhesions of the gallbladder to the first portion of the duodenum. A typical palliative gastrectomy was performed and gastro-intestinal continuity was restored with a posterior gastrojejunostomy of the Hofmeister type. The duodenum and surface of the gallbladder were drained through a stab wound.

*Pathology.*—The resected specimen measured 14 cm. along the lesser curvature and 16 cm. along the greater curvature. There was evidence of chronic gastritis.

Postoperatively, the patient developed a moderately severe bronchopneumonia and a peri-anal abscess. His wound healed well. No ulcer could be found roentgenographically on December 6, 1937, 23 days after operation. Test meal studies, done on November 30, 1937, disclosed no free acid and a combined acidity of 34 millimoles per cent. Another test meal, December 2, 1937, also disclosed no free acid. He was discharged on December 9, 1937, his 26th postoperative day.

The patient has been seen frequently in the Follow-up Clinic. He continued to feel well and had no gastric complaints whatsoever. Gastroscopy in January, 1938, had disclosed a complete disappearance of the lesion. He was last seen in the Follow-up Clinic on March 22, 1944, at which time he was completely free from gastro-intestinal symptoms. When he was next sent for, a letter was received from his wife stating that he had been well until November 15, 1944, when he had suddenly been taken with severe headache, fever, rapidly ensuing quadriplegia and death. A letter received from Morrisania Hospital, where he died, stated that the cause of death was probably a cerebral accident. No postmortem examination was performed.

CASE 2.—No. 415549: J. S., a 50-year-old male, was admitted, October 18, 1937, complaining of abdominal pain of six months duration. The pain had been growing progressively more severe and more frequent. Occasionally food relieved his pain for a few minutes. The patient had lost 20 pounds in weight during this time and had experienced a pronounced loss of appetite during the preceding two months. Several tarry stools had been noticed in the two weeks preceding entry to the hospital. During the five days prior to admission he had vomited repeatedly and had noticed amelioration of his pain after the emesis. Past history was essentially noncontributory except for the fact that the patient had noticed dyspnea and precordial pain on exertion.

Physical examination disclosed a thin, middle aged male who appeared to have lost considerable weight. The heart and lungs were essentially normal. There was moderate peripheral sclerosis. The blood pressure was 142/90. There was definite upper abdominal tenderness, but no spasms or masses were palpated. The weight was 113 pounds. The urine was negative. Hemoglobin was 90 per cent; the white blood count was 11,500, with an essentially normal differential count. The blood chemistries were reported: urea 20 mg. per cent, sugar 140 mg. per cent. The Wassermann was negative. The Rehfuss test meal disclosed a free acidity of 40 and a combined acidity of 68 millimoles per cent. No occult blood was found in the stool.

Gastro-intestinal roentgenograms disclosed a perforating lesion on the posterior wall near the lesser curvature in the region of the reëntrant angle. The lesion was 1.5 inches in diameter. The duodenal bulb showed a persistent deformity on the greater curvature side.

Gastroscopy disclosed a circular, sharply outlined ulcer on the lesser curvature and posterior wall of the stomach. It had the appearance of a benign ulcer.

The patient was treated medically for three weeks after which roentgenographic examination disclosed the gastric lesion to have diminished in size. Clinically, however, the patient evidenced no improvement, and in view of the persistent pain which had yielded slightly, if at all, to diet and medication, it was felt that operation was indicated.

The patient was explored, November 19, 1937, under avertin-ethylene anesthesia. The stomach was normal in size. Above the reëntrant angle was a definite gastric ulcer infiltrating the body of the pancreas. The duodenum was normal. Because of the high position of the ulcer, and its infiltration into the pancreas, it was decided that a palliative gastrectomy should be done. Accordingly, a typical palliative gastrectomy, leaving the gastric ulcer *in situ*, was performed. Gastro-intestinal continuity was restored by a retrocolic gastrojejunostomy of the Hofmeister type.

*Pathology.*—The resected specimen measured 11 cm. along the lesser curvature and 17 cm. along the greater curvature. The mucous membranes showed evidence of chronic gastritis.

Postoperatively, the patient developed a bronchopneumonia and temperature as high as 103.6° F. This subsided quite rapidly, however, and the patient was making a satisfactory convalescence when, on the eighth day, shortly after the through-and-through sutures had been mistakenly removed, the patient suffered a wound separation during a paroxysm of coughing. The liver appeared in the wound. This was packed back with iodoform gauze and strapped across. No further complications ensued, and the patient was discharged on the 24th postoperative day.

The patient was seen frequently in the Follow-up Clinic. He was completely asymptomatic, had gained 22 pounds, and never suffered pain, vomiting, or bleeding. The last gastroscopy was performed on January 29, 1945, at which time the residual stomach was found to be completely normal. There was no evidence of the previous ulcer. He had been repeatedly roentgen-rayed but no ulcer had ever been found. His last roentgenologic examination was performed on January 19, 1945. No evidence of ulcer was seen. Test meals had been done on many occasions and had failed to show any free acid. On July 2, 1945, a test meal revealed no free acid, and a combined acid of 8 millimoles per cent. On March 6, 1946, another test meal showed no free acid and a combined acid of 10 millimoles per cent. The patient was last seen on March 6, 1946, and was in excellent health.

CASE 3.—No. 416478: J. G., a 58-year-old male, was readmitted, November 10, 1937, complaining of abdominal pain of one year's duration. He had been treated in the hospital five months previously for a known gastric ulcer. He improved with medical therapy and was discharged. However, he continued to lose weight and strength, the pain recurred and became progressively more severe, and vomiting occurred with increasing frequency.

Physical examination disclosed a slight, chronically ill male, showing evidences of recent weight loss. The heart and lungs were essentially negative. There was marked peripheral sclerosis. The blood pressure was 140/78. There was slight tenderness in the epigastrium. He weighed 85 pounds. The urine was negative. The hemoglobin was 83 per cent, the white blood count 11,200, the differential was normal. The blood urea nitrogen was 17 mg. per cent. The Wassermann test was negative. The Rehfuss test meal showed a free acid of 70 and a combined acid of 84 millimoles. The stool did not contain occult blood.

Gastro-intestinal roentgenograms showed a penetrating gastric ulcer about one inch in diameter on the posterior wall near the lesser curvature, just below the level of the cardia.

Gastroscopy disclosed a punched-out ulcer high on the lesser curvature. The electrocardiogram disclosed occasional auricular extrasystoles, high P waves, QRS low in I, high in II. This configuration is seen in an asthenic type of heart.

The patient was treated medically but his pain continued and it was finally felt that surgical intervention was imperative.

At operation, an ulcer about two inches in diameter was found on the lesser curvature just below the esophagus, penetrating into the pancreas. There was evidence of a healed duodenal ulcer. It was felt that removal of the gastric ulcer would entail a total gastrectomy, which was not indicated. Accordingly, a palliative partial gastrectomy was performed, leaving the ulcer *in situ*. Gastro-intestinal continuity was restored by a retrocolic isoperistaltic gastrojejunostomy of the Hofmeister type.

*Pathology.*—The resected specimen measured 9 cm. along the lesser curvature and 14 cm. along the greater curvature. The microscopic examination disclosed chronic gastritis.

The first postoperative morning the temperature was 100° F.; pulse 100; the tongue moist; the abdomen soft. Later that day, however, the patient suddenly developed acute pulmonary edema, together with marked shock. The pulse rose to 190, and the blood pressure fell to 64/40. The patient exhibited no evidences of bleeding. He was placed in an oxygen tent, a phlebotomy performed, 50 per cent glucose was administered intravenously, morphine and atropine given by hypodermic injection. Despite energetic therapy, the patient ceased two hours after the onset of the attack. The medical consultant who saw the patient felt that the incident represented an acute coronary artery thrombosis with left ventricular failure.

A postmortem examination could not be obtained.

CASE 4.—No. 436884: H. R., a 54-year-old male, was readmitted, February 28, 1939, complaining of abdominal pain and vomiting. His original admission to the hospital had been on December 27, 1937, at which time he gave a history of having suffered from attacks of severe abdominal pain, partially relieved by food or soda, during the past ten years. Physical examination had disclosed epigastric tenderness and an epigastric hernia. Roentgenograms had revealed a large penetrating gastric ulcer well above the reëntrant angle, and a deformed duodenal bulb. Gastroscopically, the lesion was suspicious of malignancy. The patient's symptoms regressed and the size of the ulcer diminished after three weeks of conservative ulcer therapy. Despite this, operation was advised, because of the still present suspicion of malignant disease. The patient, however, refused permission for operation, and left the hospital. He was followed in the Out-patient Department and was gastroscoped again one year later (January 30, 1939). The picture was essentially unchanged. He returned to the hospital, February 28, 1939, because of continued pain, unrelieved now by food or alkalies, anorexia, heart burn, loss of 12 pounds, and occasional vomiting.

Physical examination revealed a thin, chronically ill male. The heart and lungs were essentially normal. Blood pressure 120/75. There was slight epigastric tenderness and an easily reducible epigastric hernia. Weight 122 pounds. Urine was negative. The hemoglobin was 73 per cent, the white blood count 11,000, with a normal differential count. The blood urea was 19 mg. per cent. The Wassermann test was negative. The Rehfuss test meal showed a free acid of 55 millimoles per cent and a total acidity of 80 millimoles per cent. Examination of the stool revealed no occult blood.

Gastro-intestinal roentgenograms revealed a gastric ulcer well above the reëntrant angle. The penetration seen on previous roentgenologic examination was no longer present. The duodenal bulb was deformed.

Gastroscopy visualized a large gastric ulcer on the posterior wall adjacent to the lesser curvature, extending half way to the greater curvature. The gastroscopist again reported the lesion to be very suspicious of neoplastic disease.

Exploratory celiotomy was performed on March 18, 1939, under general inhalation anesthesia, through a midepigastric incision. There was an acutely inflamed, and very edematous lesion on the posterior wall of the stomach, well above the reëntrant angle. It was infiltrating into, and adherent to, the pancreas. There was a scar on the anterior wall of the duodenum. The stomach was opened and the ulcer palpated from within. The actual ulceration was about 1.5 inches in diameter, but the induration and inflammation was about four to five inches in size. There were many surrounding nodes.

a few of which were removed for examination. A typical palliative gastrectomy was performed. The gastric ulcer was left *in situ*. Gastro-intestinal continuity was restored by means of an antecolic gastrojejunostomy of the Hofmeister type.

*Pathology.*—The resected specimen measured 8 cm. along the lesser curvature and 17 cm. along the greater curvature. (The specimen was apparently poorly preserved and had shrunken considerably.) Microscopic examination revealed chronic gastritis. The lymph nodes contained no malignant cells.

The postoperative convalescence was complicated by a gastric atony which gradually cleared up. He was discharged on the 16th postoperative day. A Rehfuss test meal performed on this day revealed no free acid; the combined acid measured 33 millimoles per cent.

The patient has been seen frequently in the hospital and in the Follow-up Clinic. Six weeks after discharge he developed an abscess on his larynx which required a tracheotomy and incision and drainage. In January, 1944, an appendicectomy was performed for acute gangrenous appendicitis. He was again admitted in February, 1944, for treatment of arteriosclerotic cardiovascular disease.

The patient has been free from gastric symptoms. He has gained about ten pounds and has been working.

He has been roentgen-rayed repeatedly, but no sign of the ulcer has ever been found. He was last examined roentgenologically on May 23, 1945, at which time no pathologic findings were noted.

Rehfuss test meal performed on January 29, 1945, again showed no free acid. Combined acids measured 14 millimoles per cent.

The patient was gastroscoped on October 29, 1945. No evidence of gastric or gastrojejunal ulceration was seen. There was observed a depressed scar of the healed gastric ulcer.

CASE 5.—No. 463475: M. T., a 61-year-old male, was admitted, October 5, 1940, complaining of intermittent epigastric pain, of one and one-half years duration. The pain had at first been mild and had been relieved by a hot water bag. Ingestion of food had given no relief. The pain had increased in severity and frequency, and had been more recently accompanied by radiation of the pain to the lower back, vomiting, and a loss of six pounds in weight. The past history was noncontributory.

Physical examination disclosed an emaciated male who appeared to have lost more than the admitted six pounds. There were numerous rhonchi throughout both lungs. Moderate peripheral sclerosis was present. Blood pressure 98/70. A somewhat irregular liver edge was palpable 2.5 inches below the costal margin. No masses or tenderness were present. The patient weighed 94 pounds. The urine was negative. The hemoglobin was 81 per cent; the white blood count was 11,500, and the differential count was normal. The blood chemistries were reported: urea 15 mg. per cent, chlorides 585 mg. per cent, $CO_2$ combining power 64.3 vol. per cent. The Wassermann was negative. The Rehfuss test meal disclosed a free acid of 65 and combined acids of 90 millimoles per cent. Repeated stool examinations failed to disclose occult blood. The electrocardiogram disclosed changes suggesting myocardial disease.

Gastro-intestinal roentgenograms (Fig. 1A) revealed a wide deep incisure on the greater curvature extending to the lesser. A small pocket, which is probably an ulcer, was seen on the lesser curvature above the incisure. The duodenal bulb was deformed.

Gastroscopy visualized a large ulcer on the anterior wall and lesser curvature above the incisura. It had a grayish, nodular base and the margins were undermined. The lesion was suspicious of a malignant ulceration.

The patient was explored, November 14, 1940, under cyclopropane anesthesia. A gastric ulcer was found high on the lesser curvature, near the esophagus. The lesion was somewhat posterior, and its crater extended into the pancreas. In the first portion of the duodenum was the scar of a healed duodenal ulceration. A typical palliative partial gastrectomy was performed, the gastric ulcer being left *in situ*, and

gastro-intestinal continuity was restored by means of a retrocolic gastrojejunostomy of the Hofmeister type. The closed duodenum was drained through a right subcostal stab incision, because of the friability of the tissues.

*Pathology.*—The resected specimen measured 7 cm. on the lesser curvature and 19 cm. on the greater curvature. The microscopic examination disclosed chronic and acute gastritis.

Postoperatively, the patient developed a profuse duodenal leak on the sixth day, but this diminished rapidly in amount, and the drainage stopped shortly after removal of



FIG. 1-A FIG. 1-B

FIG. 1-A.—Case 5: Roentgenogram of high lesser curvature ulcer.
FIG. 1-B.—Case 5: Roentgenogram of stomach 4.5 years after palliative gastrectomy.

the duodenal drain on the 11th postoperative day. He was discharged on the 18th postoperative day.

The patient has been seen repeatedly in the Follow-up Clinic. He gained 20 pounds in weight, and had no complaints. Test meals, on June 29, 1941 and July 2, 1945, disclosed no free acid, combined acids of 30 millimoles per cent maximum.

Gastroscopy, April 3, 1945, disclosed no evidence of ulcer. There was no atrophic gastritis present. Roentgenologic examination of the stomach was performed on April 11, 1945 (Fig. 1B). No evidence of ulcer disease was found.

The patient was last seen in the Follow-up Clinic, March 9, 1946, at which time he was in excellent health.

CASE 6.—No. 466833: I. A., a 53-year-old male, was readmitted, December 21, 1940, complaining of abdominal pain and dysphagia. His original admission to the hospital had been on January 14, 1939, at which time he had suffered from abdominal pain for six years. Exploratory celiotomy had disclosed a perforation of the gallbladder into a well walled-off indurated mass. The gallbladder was chronically inflamed and contained two stones. Cholecystectomy was performed, and the patient made an uneventful recovery. He had been well until a year before his next admission when he began to suffer from attacks of upper abdominal pain unrelated to, and unrelieved by food. The attacks often occurred at night, awakening him from sleep and, more recently, the

pain had been radiating through to the back. Marked constipation had been present. He had suffered no weight loss. For four weeks he had been having difficulty swallowing solid food and often the food would seem to "stick in his throat," and would be subsequently regurgitated. The past history was noncontributory.

Physical examination disclosed an elderly, well-developed male. The heart and lungs were essentially normal. Blood pressure 130/90. There was a well-healed right upper rectus incision. No abdominal masses or tenderness were present. The weight was 120 pounds. The urine was negative. The hemoglobin was 98 per cent;

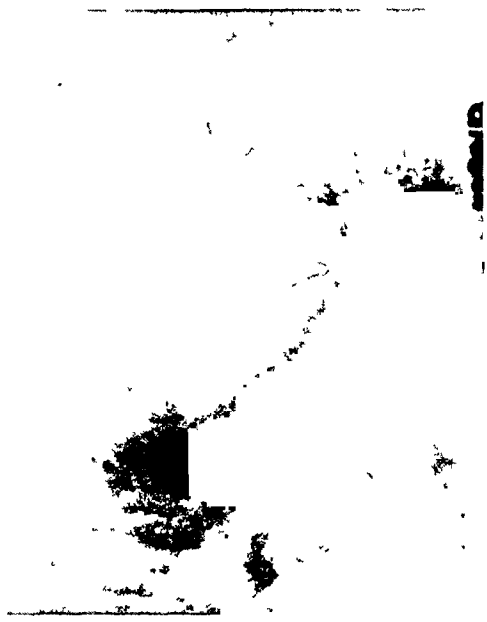


FIG. 2-A



FIG. 2-B

FIG. 2-A.—Case 7: Roentgenogram of high lesser curvature ulcer.
FIG 2-B.—Case 7: Roentgenogram of stomach one year after palliative gastrectomy.

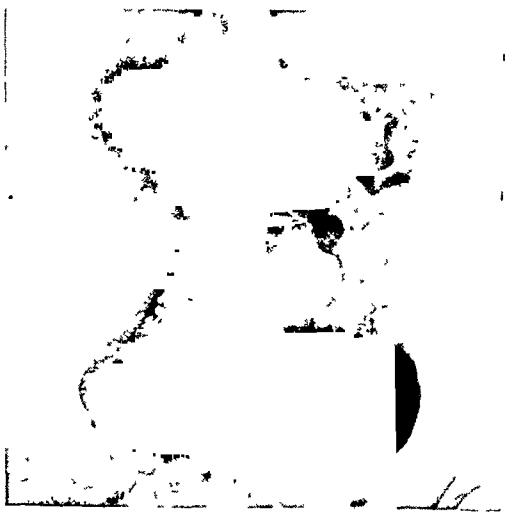


FIG. 3-A

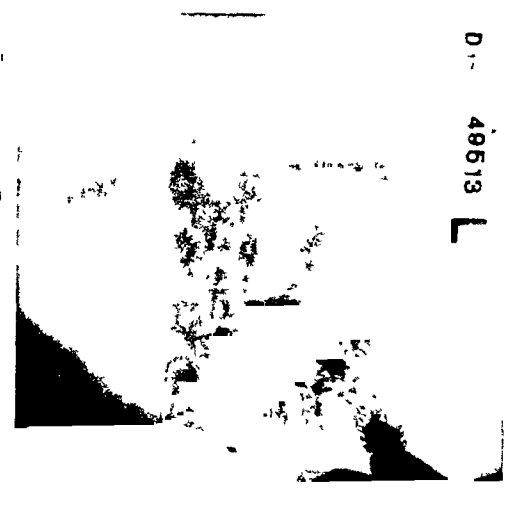



FIG. 3-B

FIG. 3-A.—Case 8: Roentgenogram of high lesser curvature ulcer.
FIG. 3-B.—Case 8: Roentgenogram of stomach one year after palliative gastrectomy.

white blood count 7,900, with a normal differential count. Blood urea was 30 mg. per cent. The Wassermann was negative. The Rehfuss test meal disclosed a perceptible amount of free acid to be present. The combined acidity was 15 millimoles per cent.

Gastro-intestinal roentgenograms disclosed a large neoplasm involving the cardiac end of the stomach. There was a 25 per cent residue at the six-hour observation.

Esophagoscopy disclosed some thickening and rigidity of the cardia. A biopsy of the terminal esophageal mucous membrane was reported "esophageal mucosa without significant change." Gastroscopy was not performed.

The patient was explored, January 10, 1941, under continuous spinal anesthesia augmented by sodium pentothal intravenously. Numerous adhesions were dissected free. A juxta-esophageal gastric ulcer penetrating into the liver and pancreas was found. Because of the extremely high location of the ulcer a typical palliative gastrectomy was performed leaving the gastric ulcer *in situ*. Gastro-intestinal continuity was restored by an antecolic gastrojejunostomy of the Hofmeister type.

Postoperatively, the patient experienced an uneventful convalescence. The wound healed by primary union. A Rehfuss test meal, 21 days after operation, revealed no free acid.

*Pathology.*—The resected specimen measured 8 cm. along the lesser curvature and 21 cm. along the greater curvature. The mucous membrane showed evidence of chronic gastritis with multiple healed erosions.

The patient was seen frequently in the Follow-up Clinic and in the Gastro-intestinal Clinic. At first he had had occasional cramps after eating but this eventually disappeared. A Rehfuss test meal, June 20, 1941, showed no free acid present, maximum combined acidity was 20 millimoles per cent. The patient was last seen in the Follow-up Clinic, March 21, 1946, at which time he looked and felt well, and had no pain, no vomiting, no bleeding and no dysphagia. Roentgenologic examination, April 14, 1945, had disclosed no ulcer; the rugae were unusually prominent. Gastroscopy, April 7, 1945, had revealed no erosions or ulceration, and no evidence of the previous ulceration.

CASE 7.—No. 513023: H. H., a 54-year-old male, was admitted, November 12, 1943, complaining of epigastric pain and burning of three years' duration. The pain had been subject to exacerbations and remissions and was usually relieved by the ingestion of food. He had been treated in the Out-patient Department with diet and medication. Two weeks before admission the pain had become more severe, had radiated through the abdomen to the back, and the patient was advised to enter the hospital. The past history was noncontributory.

Physical examination was essentially negative. The urine was normal. The hemoglobin was 92 per cent, the white blood count normal. The blood chemistries were reported: urea 20 mg. per cent, chlorides 575, $CO_2$ 72 vol. per cent. The Wassermann was negative. The Rehfuss test meal revealed a free acid of 20, total acid of 55 millimoles per cent.

Gastro-intestinal roentgenograms (Fig. 2A) disclosed a penetrating gastric ulcer ¾-inch in diameter, high up on the posterior wall and lesser curvature of the stomach.

Gastroscopy disclosed a gastric ulcer 3 cm. in diameter located on the posterior wall and lesser curvature, located about 3 cm. from the esophagus.

The patient was explored, November 15, 1943, under continuous spinal anesthesia. Juxta-esophageally was a penetrating gastric ulcer attached to the pancreas and causing a great deal of induration and edema of the stomach wall. There were many surrounding lymph nodes, two of which were removed for biopsy. A typical palliative partial gastrectomy was performed, the ulcer being left *in situ*, and gastro-intestinal continuity was restored by an anterior terminolateral gastrojejunostomy of the Hofmeister type.

*Pathology.*—The resected specimen measured 4 cm. along the lesser curvature and 19 cm. along the greater curvature. The microscopic report of the stomach and nodes was unfortunately lost.

The patient had an entirely uneventful postoperative convalescence and was discharged on the 14th day.

The patient has been seen repeatedly in the Follow-up Clinic. He has remained symptom-free and has gained weight and strength. Roentgenograms of the stomach, January 15, 1945 (Fig. 2B), disclosed no ulcer. Gastroscopy was performed on January 31, 1945, and disclosed merely a depressed scar of the previous ulceration. Rehfuss test meal was done on January 10, 1945. There was no free acid; total acidity measured 18 millimoles per cent. The test meal was repeated, February 27, 1941, and revealed no free acid; combined acidity of 10 millimoles per cent. He was last seen in the Follow-up Clinic, February 20, 1946, and was in excellent health.

CASE 8.—No. 515771: R. K., a 60-year-old female was admitted, January 24, 1944, complaining of loss of appetite during the past two years and a 60 pound weight loss in the past six months. She reported no pain or vomiting. On repeated questioning, however, she admitted to some upper abdominal distress after meals. The past history was essentially noncontributory.

Physical examination disclosed an emaciated chronically ill female. The heart and lungs were negative. The blood pressure was 184/90. The abdomen was soft, nontender, and no masses were palpable. The patient's weight was 81 pounds.

The urine was negative. Hemoglobin was 52 per cent, red blood count 3,490,000; white blood count 15,450, with a normal differential count. The blood chemistries were reported: urea 10 mg. per cent, sugar 85 mg. per cent, chlorides 450 mg. per cent, the $CO_2$ combining power 59.2 vol. per cent, total proteins 7.3 grams per cent. Blood Wassermann negative. The stool examination for occult blood was markedly positive on more than one occasion. The Rehfuss test meal revealed a free acid of 30 and total acids of 55 millimoles per cent.

Gastro-intestinal roentgenograms (Fig. 3A) revealed a large penetrating ulcer on the lesser curvature and posterior wall of the stomach about two inches below the cardia. The crater was about two inches in diameter. There was considerable displacement of the mucosal pattern, which might have been due to malignancy or an inflammatory mass. There was a 25 per cent residue at the end of six hours.

Gastroscopy disclosed a large polypoid tumor involving the posterior wall and presenting an ulcer about 4 cm. wide at its summit. The proximal edge appeared to be about 5 cm. below the esophagus. The impression was polypoid carcinoma with atrophy of the mucosa.

The patient was thought to have a neoplasm of the stomach and was prepared for operation with repeated transfusions, intravenous fluids, parenteral vitamins and daily gastric lavages.

Exploratory celiotomy was performed, February 10, 1944, under spinal anesthesia, supplemented later with general inhalation anesthesia. The upper portion of the lesser curvature was greatly thickened and inflamed and was markedly adherent to the liver and pancreas. The lesion appeared to be an inflammatory process. The stomach was opened and the lesion was palpated from within. Just below the esophagus, on the lesser curvature, was a punched-out ulcer one inch in diameter. A typical palliative partial gastrectomy was performed, the ulcer being left *in situ*. A terminolateral antecolic gastrojejunostomy of the Hofmeister type was performed to restore gastro-intestinal continuity. A jejunostomy for alimentation was instituted.

*Pathology.*—The resected specimen measured 8 cm. along the lesser curvature and 20 cm. along the greater curvature. The microscopic examination disclosed no significant findings.

The postoperative course was uneventful until the eighth postoperative day, when the patient became markedly distended, and developed the clinical picture of large bowel obstruction. A tube cecostomy was performed and the patient recovered rapidly. Subsequently a barium enema failed to disclose any colonic pathology. Un-

eventful recovery ensued after this temporary set-back for which no cause had been found. The jejunostomy tube was removed on the 15th postoperative day.

On March 11, 1944, gastroscopy was repeated. The ulcerated area, previously observed, now appeared as a depressed scar about 1.5 cm. wide.

The patient's weight on the day of discharge, 30 days after the original operation, was 73.5 pounds.

The patient was last seen in the Follow-up Clinic on June 13, 1945. Her weight was 106 pounds, a gain of 25 pounds. She has had no pain, no vomiting, and was having regular bowel movements daily. A Rehfuss test meal, April 11, 1945, showed no free acid. The combined acids measured 16 millimoles per cent. Gastroscopy, April 23, 1945, disclosed a depressed scarred area at the site of the ulcer visualized preoperatively. No ulceration was seen. Roentgenograms of the stomach, April 10, 1945 (Fig. 3B), showed a stomach upon which a subtotal gastrectomy had been performed. A constant incisura was present on the greater curvature opposite a point on the lesser curvature, towards which several radiating mucosal folds converge. The point of convergence corresponds to the localization of the previously described ulcer. The stoma was normal.

The patient was well until October 30, 1945, when she took suddenly ill and was taken to City Hospital (No. 136209-45). She died two days later. Autopsy revealed bronchopneumonia, chronic glomerulonephritis and arteriosclerotic heart disease. There was an old completely healed gastric ulcer.

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DISCUSSION.—DR. RICHARD H. SWEET, Boston, Mass.: It occurred to me while listening to Doctor Colp's very interesting paper that it might be appropriate to mention that this problem can be approached from a different point of view, namely, to operate upon patients with a high right gastric ulcer by the transthoracic approach. It is possible in this way to remove the ulcer in all cases and to preserve a portion of the stomach, with which one can perform an esophagogastric anastomosis. Much of the acid-producing portion of the stomach remains, but the fact that the vagus nerves have been sectioned may lead to a reduction in the secretion of acid, which may contribute to the success of the operation.

DR. RALPH COLP, New York City (closing): Of course, the advantage of Doctor Sweet's operation is that the ulcer is removed, but in the hands of most surgeons I believe the mortality would far transcend the mortality of nonremoval of a benign ulcer by a palliative gastrectomy.

# SUBTOTAL GASTRECTOMY FOR DUODENAL ULCER*

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A CERTAIN NUMBER of patients with chronic duodenal ulcer must be treated surgically. This group represents from 10 to 15 per cent of all cases of duodenal ulcer coming to a large general hospital. It consists of ulcer patients in varying degrees of chronicity who have developed cicatricial stenosis, those who bleed massively with each exacerbation, and those who continue to have pain on the best ambulatory medical regimen known. Surgeons throughout the world, by the method of trial and error, have achieved almost universal agreement regarding the type of operation likeliest to succeed in such cases. Resection of the distal stomach of sufficient extent to eliminate all the acid activating antral mucosa appears to offer the greatest opportunity for cure. To accomplish this, it is usually technically easier to include a generous portion of the acid-producing fundus. It is possible that this secondary consideration influences the results of operation in both directions. On the one hand, this makes it more certain to include all the antral cells, particularly those located high on the lesser curvature, but on the other hand, this extensive resection of fundus may well account for some of the late nutritional and functional problems that sometimes arise. The decrease in operative mortality accompanying better surgical methods in general and greater experience in particular has a tendency to increase the rate of radical *versus* conservative measures in the treatment of borderline cases.

Dragstedt and his coworkers[1] have recently suggested the possibility of avoiding most of the operations upon the stomach itself by transthoracic vagotomy. Moore, Jones, *et al.*,[2] in our clinic, have satisfactorily demonstrated in a carefully selected group of ulcer patients that this procedure is spectacular in its immediate results. It will require time and more extensive experience with this indirect attack on the problem to evaluate the ultimate outcome in these cases.

In the meantime, it is essential that the accumulated experience of surgeons who have treated duodenal ulcer by radical surgery be assembled. Rienhoff[3] has already presented his results on a large group of patients treated by partial gastrectomy. It is our intention in this report to consider only those patients primarily subjected to gastric resection for duodenal ulcer by the senior author. This will eliminate variables that would of necessity exist in data collected from the hospital as a whole. The follow-up studies, carried out mainly by the coauthor, chiefly include private cases, although some were ward patients. We have excluded a sizeable group of patients who had had previous but unsatisfactory surgery for duodenal ulcer elsewhere. We have included cases operated upon during the acute phase of massive hemorrhage.

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

INDICATIONS FOR OPERATION

*Cicatricial stenosis* results from long-standing ulcer with repeated episodes of activity. Usually these patients are in the older age-group, and present themselves in a state of malnutrition with either spontaneous or self-induced vomiting at least once in 24 hours. The stomach is large, and barium leaves the pylorus slowly. These patients improve slightly on gastric drainage and intravenous therapy. It is difficult by these methods to correct their chemical imbalance. The gastric acidity is low, and this leads to the erroneous assumption that their ulcer tendency is past. It is often assumed that these patients may be relieved by gastro-enterostomy or pyloroplasty. After observing two elderly men develop anastomotic ulcer following this reasoning, it seemed to us that more radical measures should be adopted. These patients are devoid of excess fat, and the scar of the ulcer area usually is just distal to the pylorus. These factors make them particularly satisfactory for subtotal resection. We have employed this radical type of operation upon this type of patient in recent years,[4] with no regrets.

It should be remembered that many ulcer patients become temporarily obstructed during acute exacerbations. These have a more sudden onset of symptoms occurring at any age, and enter the hospital in a good state of nutrition. Such patients always respond to gastric drainage and intravenous therapy within a week or ten days, after which time conservative treatment may be the procedure of choice.

*Massive hemorrhage* from duodenal ulcer indicates that the ulcer overlies the gastroduodenal artery or one of its radicals. Years ago, we[5] pointed out that under proper hospital management a high percentage of these patients spontaneously recover from such an episode. Certainly, death from acute anemia rarely occurred in young persons. In patients beyond the fifth decade, however, such an ulcer would not respond to conservative therapy in one-third of the cases. Whether or not a patient spontaneously ceased to bleed had no relation to the chronicity of the ulcer or the number of episodes of bleeding. Age and the degree of arteriosclerosis present seemed to be the only factors on which one could rely regarding prognosis. This led us to adopt conservative treatment in patients under the age of 45 and the careful weighing of all evidence for early operation in those beyond this age. Exceptions to this general rule have been met, and an occasional young person will bleed to death despite all that can be done. We learned early in our experience that massive hemorrhage occurring repeatedly over a period of several days is nearly always surgically hopeless. This, we believe, is due to the loss of tissue substances from lack of food absorption, which cannot be adequately replaced by artificial methods. Thus, only one patient survived radical surgery after the seventh day of bleeding. There were, however, 11 successful resections in 12 patients, all in the older age-group, who were operated upon within 72 hours of the initial hemorrhage.

It was postulated that the Meulengracht[6] system of feeding patients who

were bleeding might extend the time limit for safe operation. Also, one may consider the better operative state of such a patient who has had intravenous amino-acids, as well as blood, plasma, water, salt and sugar. So far, we are convinced that patients are not benefited by the forced ingestion of food while the intestine is filled with blood. This is particularly true when the patient has nausea and vomits blood that has passed into the stomach from the duodenum. If he is hungry, he will be improved by the ingestion of finely divided food, regardless of the stage of bleeding. The results, reported so profusely in the literature regarding the magic of feeding during massive hemorrhage, fail, in nearly every case, to take into account the age of the patients dealt with. The younger ones nearly always recover regardless of treatment, whereas a large percentage of the older patients continue to succumb unless subjected to operation early during their bleeding episode. We have assumed that this variation is due to the difficulty with which firm thrombus formation takes place in a more or less rigid arteriosclerotic blood vessel. There may well be undertermined factors influencing the situation. Huge doses of vitamin K have been helpful, since a number of these patients with massive bleeding have a measurable elevation of the prothrombin time.

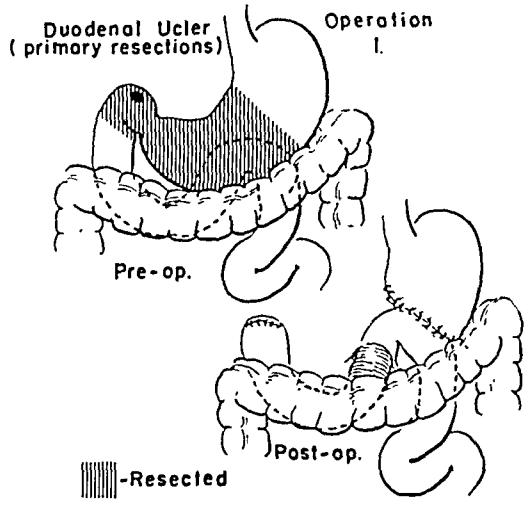



FIG. 1.—Operation I for duodenal ulcer. The resected specimen shown by heavy vertical lines includes the lower two-thirds of the stomach and the duodenal ulcer. Continuity is restored by means of a posterior Hoffmeister anastomosis.

In the interval state of the duodenal ulcer that bleeds massively on activation, one must consider seriously the advisability of such a patient's submitting to surgery at a time of election. We have been impressed by the appreciable percentage of ulcer patients who have little or no warning of exacerbations. This may be due to a high pain threshold, as pointed out by Chapman, *et al.*[7] Perhaps there is a variation in pain pathways from this region in some patients. Regardless of the explanation of this situation, those who perforate or who bleed massively without warning should, at a suitable time, be offered surgical protection against future episodes. It also appears that patients who have bled massively are less likely to remain symptom free on conservative measures than is the average person with duodenal ulcer. This may be due to the location of the ulcer under these circumstances, since healing of the completely eroded thin, posterior wall of the duodenum is represented by fixed scar tissue in or on the pancreas.

*Intractable pain* has been considered by Hinton[8] the most valid reason for subjecting a patient with duodenal ulcer to surgery. We have used this term loosely to include some patients who, with a better economic or intellectual

status, might well have continued on conservative measures. These patients have varied tremendously, and their selection for surgery has given us much concern. It is in this group that we have had some of our most outstanding successes, as well as some of our most dismal failures. These include persons who are intelligent, prosperous, happily married and otherwise well, only to have continuous discomfort when the stomach is empty of food or added alkalies. In one such patient, after three weeks of hospital management, sleep was possible only while a continuous drip of aluminum hydroxide was administered through a nasal catheter. This man, overweight from hourly feedings of milk and cream but weakened by his enforced bedrest, succumbed to coronary thrombosis 48 hours after subtotal gastrectomy. Some patients in this group, particularly those with low intelligence who are worried about finances and family and have uncoöperative and vigorous spouses, willingly submit to or even beg for surgery. They are prone to be the ones who are unhappy with the operative result and are unable to cope with life in general. They have a different set of postoperative complaints, but these are referable mainly to the gastro-intestinal tract. It is in such patients that psychiatric aid should be solicited before and not after surgery. Some such cases are referred to the surgeon by the internist because the latter believes that he cannot keep these patients well enough to do their job in life on a conservative regimen.

## TECHNICAL CONSIDERATIONS

Based on our own observations and those of others, we have assumed that the operation, if undertaken, should attempt removal of the distal two-thirds of the stomach and the ulcer-bearing segment of the duodenum. As evidenced by our early failures due to technical difficulties with the duodenal stump, it soon became obvious that, at least in our hands, the risk was too great to pursue this supposedly ideal procedure in all cases. Although it is possible by a tedious, painstaking dissection with repair or reimplantation of the common bile duct in certain inflammatory extensions from duodenal ulcer to achieve a happy outcome, this, too often led to complications, sometimes fatal, to warrant a continuation of this routine. This prompted us to do, in a small group of cases, resections for exclusion by turning in a segment of the antrum without excision of the mucosa; the results, however, were unsatisfactory. Other modifications designed to obtain an adequate resection have been more successful, and the whole series breaks-up into four main categories:

*Group I:* When patients can be operated upon during a quiescent phase, and the inflammatory reaction is at a minimum, it is usually possible to resect the ulcer area in the duodenum without difficulty. The foreshortening of the duodenum from scar tissue may, even in this chronic state, leave too little room between the ulcer and the ampulla of Vater or the hepatic artery to allow a safe and satisfactory inversion of the duodenal stump. In Group I, we have included those cases in which part or all of the ulcer scar was used in the closure of the duodenum. This may confuse the issue to some extent, but we believe that the

ultimate results are unchanged by this procedure. Thus, there are 139 cases in this group, the results of which can be seen in Table I.

*Group II:* In 18 patients the ulcer was far enough distal to the pylorus to allow a transection of the duodenum above the ulcer and to leave room for an adequate closure. In these cases, removal of the ulcer itself might have led to disturbance of the bile ducts, which we have found so tedious to repair or reimplant. Although the number of such cases is small, it appears that they have done as well as those in Group I. In some of these, if not all, we believe that even a second-stage operation on the distal segment six weeks later might have been difficult to carry out. It is important that early dissection to determine the extent of the ulceration must be done with the greatest of care. Often

TABLE I

DUODENAL ULCER—PRIMARY RESECTIONS
DISTRIBUTION OF CASES AND MORTALITY

| | Type of Operation | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | Finsterer | Total |
| Number of cases | 139 | 18 | 27 | 3 | 8 | 195 |
| Deaths | 7* | 2† | 0 | 0 | 1 | 10 |
| Mortality % | 5.1 | 11.1 | 0 | 0 | 12.5 | 5.1 |

* Includes 4 deaths—late massive hemorrhage.
† Includes 1 death—late massive hemorrhage.
Mortality, elective resections—2.6%.

this procedure, which should, up to a point, be routine, has led us into the commitment of a prolonged dissection when a less extensive alternative was available. Certainly, it is necessary in all cases in which primary resection is contemplated to determine the course and direction of the common bile duct. If, however, such maneuvers lead one into the ulcer at a low level in the duodenum, there is no other choice than to proceed with complete removal of the ulcer. In one patient where this dissection was abandoned after finding the ulcer actually in the third portion of the duodenum, death occurred from perforation of the ulcer three days after subtotal gastric resection for exclusion. On this man, we had previously closed a gastrojejunocolic fistula. He had refused further surgery until his second episode of massive hemorrhage two years later.

*Group III:* In these patients we have used transection of the antrum proximal to the pylorus with excision of the mucosa from this segment, in addition to a generous gastric resection. This method was suggested in Finsterer's[9] original communication on resection for exclusion. Later, he stated that this small segment of antral mucosa could be left *in situ* if it was accompanied by a sufficiently high gastrectomy. Finsterer subsequently regretted this, and the almost universal failure when antral mucosa has been left behind is common knowledge to us all.

There were two poor results in this group. One patient, thought to have had an adequate procedure, developed an anastomotic ulcer two years later, which healed after excision of the antral segment and the first portion of the duodenum. In this segment, antral mucosal cells were found near the pyloric ring that had apparently grown from a nidus left at the original operation. He has remained well since. Another patient since operation has had episodes of bleeding of undetermined origin. It has not been possible to demonstrate an anastomotic ulcer in his case, and gastroscopy has revealed marked gastritis in the proximal stomach segment. He could probably be relieved by a removal of the antral segment but has refused further surgery. He is obese and indulges in highly seasoned food and alcoholic beverages. In the remaining cases suitable at this time for follow-up, the results are as good as those in Group I.

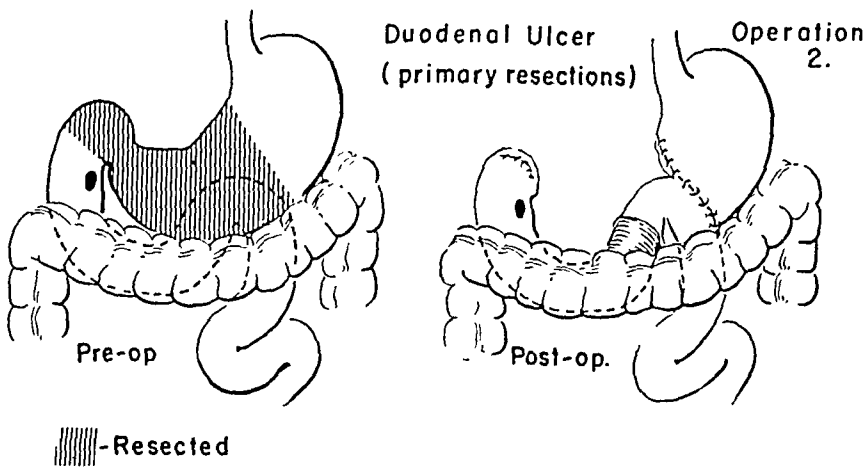



FIG. 2.—Operation II for duodenal ulcer. The resected specimen does not include the ulcer which is located in the second portion of the duodenum. Normal duodenum is closed proximal to the ulcer, thus excluding the ulcer.

The technical difficulties of complete removal of the antral mucosa and a satisfactory closure of the remaining tissue have made this procedure somewhat unpopular. With care, the mucosa can be separated without damage to the thin posterior wall of the antrum. The dissection within a more or less constricted pyloric ring is sometimes difficult, and bleeding in this area may be troublesome. We have always closed the denuded segment by inversion, but Wangensteen[10] has advocated closure by apposition, as suggested by Estes[11] and Scrimger.[12]

*Group IV:* McKittrick,[13] *et al.,* have advocated a two-stage attack on certain patients with duodenal ulcer. His premise is well taken, in that the young surgeon during his formative period may not be able to use proper judgment in the selection of procedure under all circumstances. Gastrectomy with anastomosis is a simple matter, but the management of the duodenal stump is often complicated. This is well-borne out by our early experience in this field. Six weeks after the original operation, the antral segment can be removed with

greater safety, since the inflammatory reaction about the ulcer has largely subsided. This division of the procedure has all the disadvantages of any two-stage operation. It does, however, reduce the risk in complicated cases in any hands, especially those unfamiliar with the many pitfalls encountered in such operations. Although we have deliberately planned such a procedure in only three patients, we believe that the principle is sound and should be more widely used. It is possible that all patients in Group III should be warned that a second stage may eventually be necessary. As a matter of fact, further studies may reveal that, in order of preference, Group IV should take precedence over Group III.

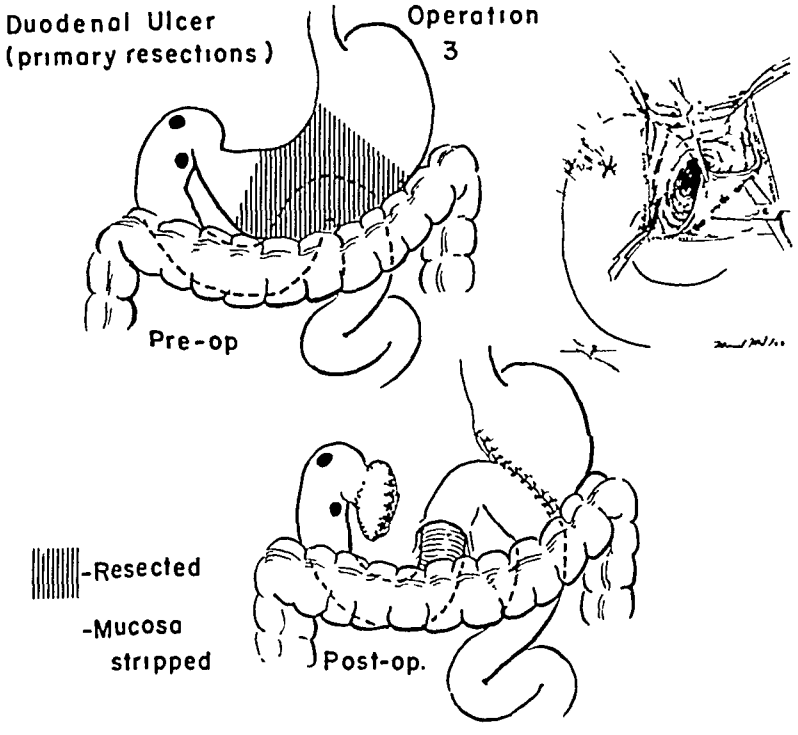



FIG. 3.—Operation III for duodenal ulcer. Inflammatory adhesions about the ulcer make it impossible to mobilize the duodenum. The stomach is transected proximal to the pylorus and the mucous membrane removed. The pyloric muscle is then closed

## OPERATIVE PROCEDURE

Transverse incisions have been used in our patients who have a flaring costal angle and in those with low-lying stomachs. This approach has some advantages but is not suitable for patients with a narrow costal angle or those with high transverse stomachs. In the latter group, we prefer a left rectus muscle-retracting incision. We believe that either of these will result in fewer weak wounds than the ones that occur following the midline approach. Interrupted nonabsorbable sutures in the fascia and careful closure of the dead space in the fat have eliminated wound dehiscence and hernia in the scar.

Inspection of the ulcer area, with sufficient lysis of adhesions to determine the relation of the inflammatory reaction to the common bile duct, is the preliminary step in the operation. One may be able to determine at this time which procedure can be more safely carried out. As mentioned before, too much dissection of this area early in the operation may result in an unnecessarily tedious and prolonged operation or leave a low-lying ulcer exposed to acute perforation.

We prefer to free the greater curvature of the stomach first, starting well above the junction of the right and left gastro-epiploic vessels. The left gastric vessels are interrupted proximal to their spread in the lesser curvature. Transection of the stomach between Payr's clamps at right angles to the curvatures is then done, including the lesser curvature at the highest level feasible. The distal

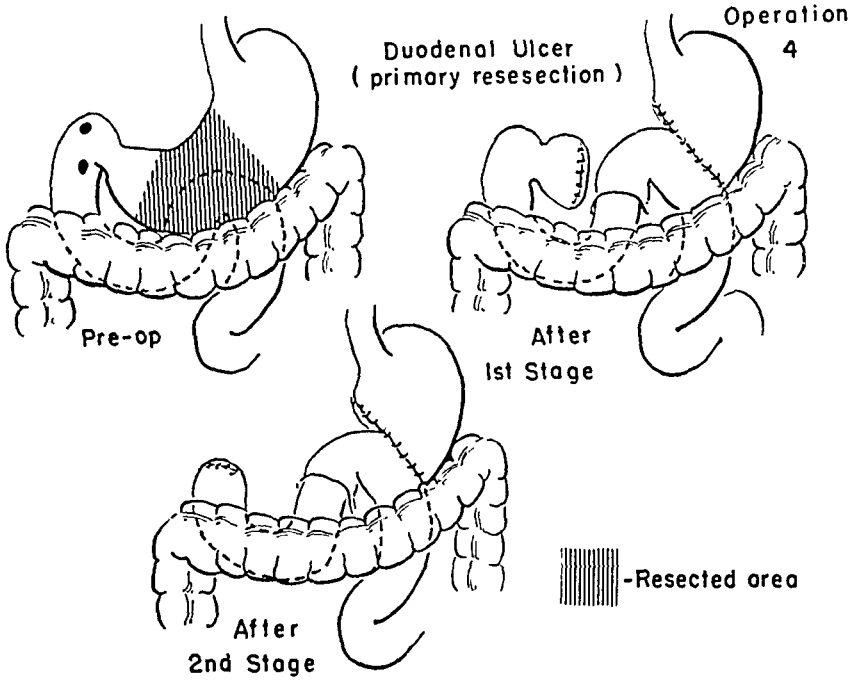



FIG. 4.—Operation IV for duodenal ulcer. The stomach is transected proximal to the pylorus. The mucous membrane is not removed, and the pylorus closed. Six weeks later, at the second stage, the pylorus and ulcer bearing portion of the duodenum are resected.

segment can then be manipulated in such a manner that the adherent area about the involved duodenum can be exposed from all directions. We have inverted the duodenal stump with two continuous rows and one interrupted row of fine chromic catgut. It requires approximately 2 cm. of free duodenum to accomplish this easily, and we have been content to leave some of the normal or abnormal adherence of the posterior duodenal wall to the pancreas distal to the suture line.

We have occasionally used the entire cut-surface of the proximal stomach segment in the anastomosis, but most often we have closed the upper third using the remaining two-thirds for the stoma. The jejunum is anastomosed to the

stomach as close to the ligament of Treitz as possible in a retrocolic isoperistaltic hook-up. The rent in the transverse mesocolon is carefully attached to the stomach segment above the anastomosis with interrupted cotton sutures. Two rows of fine continuous chromic catgut only are used in the anastomosis, with care to invert all of the mucous membrane.

Several years ago, we[14] advocated jejunostomy for feeding in pre- and postoperative stomach resections. Later we[15] suggested proximal jejunostomy for decompression of the postoperative stomach. The latter procedure has been used by us in 246 patients. The feeding jejunostomy is not routine but is useful in patients who are below par preoperatively. Lately, we have used this tube routinely in an attempt to prevent weight-loss during early convalescence. No fatal complication has resulted from the use of either of these tubes. No case of intestinal obstruction has occurred as we feared might take place around the fixed point. Three cases of minor localized infection within the peritoneal cavity have occurred, delaying discharge from the hospital about one week. One erosion of the deep epigastric artery required exposure and ligature. We often insert the tubes and then use only the proximal one intermittently for two or three days. Occasionally these tubes are invaluable in the management of a temporarily malfunctioning stoma. Patients are grateful for the elimination of the nasal catheter postoperatively. A few have complained of mild discomfort at the site of the fixed jejunum to the abdominal wall for a short while after discharge from the hospital. Minor infection about the tube is usual. We believe that the tubes should not be withdrawn until after the 12th postoperative day. No patient has developed a fistula at this site. After removal of the tube, there is practically no discharge of jejunal contents and the wounds are dry within 48 hours.

### IMMEDIATE RESULTS

In tabulating the results from operations on the stomach, one must bear in mind factors that may influence our deductions. The operative mortality is fixed and definite, and may not be so important when dealing with otherwise hopeless situations. It is, however, to be remembered that duodenal ulcer is a benign lesion that usually responds to conservative measures. It may be debated whether or not we should justifiably consider the late efforts to rescue patients dying from massive bleeding as operative fatalities. When, however, the opportunity comes at a time known to the surgeon as "too late," it is difficult for him to refuse, since a rare success occurs under these circumstances. There is no doubt concerning the value of experience regarding mortality, but everyone can point out a reduction in deaths during the past few years. The elimination of peritonitis and pulmonary complications often attributed to the advent of chemotherapeutic agents may, in fact, be mainly due to advances in preparation, anesthesia, surgical technic and aftercare.

Reference to Table II will show that there were five deaths in the patients who had resection at the time of election. Two were due to coronary thrombosis, and one to pneumonia. Two patients with large ulcers died postoperatively of

peritonitis. With the exception of one of the deaths from coronary thrombosis, all occurred in the era before the introduction of sulfonamides and penicillin.

The patients who died after operation for acute massive hemorrhage were uniformly operated upon after several days of bleeding as a final gesture. The five patients who succumbed under these circumstances died within a few days after operation. If they survived the period of hemorrhage and shock, they died promptly of peritonitis or pneumonia.

The advent of better anesthesia, chemotherapy and frequent transfusion has been of immense aid in lowering the mortality. Thus, the mortality in the first 50 cases of this series was 12 per cent, and that of the next 50 was six per cent, whereas in the last 100 there was only one death. A series of cases extending throughout 1942, 1943, 1944 and a portion of 1945 was broken after 103 successes by the death from coronary occlusion mentioned above.

TABLE II

DUODENAL ULCER—PRIMARY RESECTIONS
COMPLICATIONS AND DEATHS

| | Elective Resections | | Late Resections for Acute Massive Hemorrhage | |
|---|---|---|---|---|
| | Nonfatal | Fatal | Nonfatal | Fatal |
| Hemorrhage, shock | 1 | 0 | 0 | 2 |
| Sepsis: | | | | |
| Peritonitis | 0 | 2 | 0 | 1 |
| Leaking duodenal stump | 1 | 0 | 0 | 1 |
| Necrosis antral stump | 1 | 0 | 0 | 0 |
| Leak at jejunostomy site | 1 | 0 | 0 | 0 |
| Wound sepsis | 2 | 0 | 0 | 0 |
| Pancreatic abscess | 1 | 0 | 0 | 0 |
| Cardiorespiratory: | | | | |
| Pneumonia | 0 | 1 | 0 | 1 |
| Atelectasis | 3 | 0 | 0 | 0 |
| Coronary thrombosis | 0 | 2 | 0 | 0 |
| Thrombo-embolism | 6 | 0 | 0 | 0 |
| Stomal obstruction | 5 | 0 | 0 | 0 |
| Miscellaneous: | | | | |
| Minor dehiscence | 1 | 0 | 0 | 0 |
| Diazine reaction | 1 | 0 | 0 | 0 |
| Ulnar paralysis | 1 | 0 | 0 | 0 |
| Total | 24 | 5 | 0 | 5 |

Nonfatal complications during immediate convalescence are rarely emphasized. They are, however, occasionally so serious that one considers them sublethal in character. Pulmonary emboli from bland thromboses in the deep veins of the leg are now so well recognized as a possible complication following bedrest that one should be able to eliminate most of them. On the other hand, those who are particularly alert to this possibility still have patients whose immediate recovery is prolonged by pulmonary infarcts. Fortunately, we have had little trouble with leaking or bleeding suture lines. We have not found it necessary to reëxplore the patient for malfunctioning stoma since we have employed double jejunostomy tubes. Collections of pancreatic fluid, following the

removal of duodenal ulcers penetrating the pancreas, have caused us much concern on occasion. We have found it necessary to drain such areas secondarily in a few cases. In one patient, gradual stenosis of the transpancreatic portion of the common bile duct occurred, requiring reëstablishment of continuity six months later by a method previously described by us.[16] The stormy convalescence occasionally seen is ever present in our minds. We realize that the narrow margin of safety, under these circumstances, could easily influence mortality results. It is possible to avoid most of these disturbing situations by the proper selection of the type of procedure chosen to fit the conditions met.

TABLE III

DUODENAL ULCER—PRIMARY RESECTIONS
DISTRIBUTION OF FOLLOWED CASES

| | Type of Operation | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | Finsterer | Total |
| Followed 1-14 years | 93 | 14 | 21 | 1 | 7 | 136 |
| Too early for evaluation | 24 | 1 | 5 | 2 | 0 | 32 |
| Operative deaths | 7 | 2 | 0 | 0 | 1 | 10 |
| Lost | 15 | 1 | 1 | 0 | 0 | 17 |
| Total | 139 | 18 | 27 | 3 | 8 | 195 |

## LATE RESULTS

In embarking on a radical attempt to relieve a patient with duodenal ulcer no longer responsive to conservative treatment, one must take into consideration the ultimate as well as the immediate result.

To be eligible for follow-up studies, it was necessary to exclude operations performed in 1945 and 1946, since it is still too early to evaluate the results. Seventeen patients have been lost, leaving 136 available for study (Table III).

In judging the late results of operation, we have eliminated the small group of Finsterer resections, which we soon found were entirely unsatisfactory (Table IV).

The remaining 129 patients were classified as excellent, satisfactory, or poor (Table V). Patients graded "excellent" and entirely asymptomatic comprised 69 per cent of the entire group. An additional 18 per cent had trivial symptoms, such as intolerance to a fatty meal or a rare attack of nausea after a heavy meal; these, too, were included in the excellent results. About six per cent of the patients were improved by the operation but still have symptoms requiring a special diet or medical care; these results are listed as "satisfactory." Definitely poor results occurred in about seven per cent of the group.

A happy outcome accompanying a smooth convalescence with continued freedom from pain and other disturbances takes place in the large majority of cases. Patients enthusiastically state that they are free of discomfort for the first time in many years and that they eat anything they choose and as much of

it as they can get. They work harder than ever before and wonder why this relief had not been offered to them earlier in their lives. Many others are relieved of ulcer pain but continue to eat small meals because of discomfort or nausea accompanying overindulgence.

Persistent gastro-intestinal symptoms of some degree will occur in about a third of the cases. Those that occur in the excellent and satisfactory groups are analyzed in Table VI. The most frequent residual symptom is that of a "small stomach," *i.e.,* the inability to eat a full meal and discomfort, gas or nausea after eating. Less common, but more troublesome, are the symptoms of the "dumping stomach." Such patients have a sense of exhaustion or weakness after meals and occasionally have a rapid pulse, perspiration or vertigo, followed by diarrhea or lower abdominal cramps. These symptoms are often

TABLE IV

DUODENAL ULCER—PRIMARY RESECTIONS
FOLLOWED CASES—RESULTS ACCORDING TO TYPE OF OPERATION

| | I | II | III | IV | Finsterer | Total |
|---|---|---|---|---|---|---|
| Excellent | 82 | 12 | 17 | 1 | 1 | 113 |
| Satisfactory | 5 | 1 | 2 | 0 | 0 | 8 |
| Poor | 6 | 1 | 2 | 0 | 6 | 15 |
| Total | 93 | 14 | 21 | 1 | 7 | 136 |

alleviated by dietary measures. This group is especially intolerant of a high-fat intake and can be benefited by a high-protein diet. Most of the symptoms listed in this table are not important enough to trouble the patient, and can be elicited only by careful questioning; they do occur, however, in nearly a third of our postoperative patients. It must be remembered, in this regard, that a control series of theoretically normal people will show similar symptoms in 10 to 20 per cent of the group (St. John, *et al.*[17]).

Weight changes after resection are interesting. A considerable number of patients gain weight, whereas a larger percentage have difficulty acquiring their normal weight and cannot eat enough to gain while carrying on their work. It will be noted that although weight-loss is frequent, symptoms arising from it are unusual. Men appear to have less difficulty in this regard than women. Young and middle-aged men feel well at their "college weight" and are somewhat proud of it, whereas the older man resents his appearance. It is difficult to see why two individuals having the same amount of stomach removed should behave so differently. We agree with Rienhoff that weight-loss never becomes a problem to the gourmet, and that the patient who has never really enjoyed food has more difficulty in taking an adequate number of calories each day. We find that the average weight-loss is nearly twice as high in women as it is in men. Patients who have been operated upon for obstruction lose the least weight, whereas those whose resection was for pain or bleeding lose the most. (Table VII).

Paralleling these weight changes, it is also of interest that the postoperative results are better in men than in women (Table VIII). Women appear to have more symptoms from the small postresection stomach than do men, and in view of the rarity of jejunal ulcer in women, it is possible that resection should be less radical in women than in men.

The results classified as poor fall into three groups: anastomotic ulcers, recurrent gastric hemorrhages and severe postresection symptoms (Table IX).

TABLE V

DUODENAL ULCER—PRIMARY RESECTIONS
FOLLOWED CASES—RESULTS
(*Finsterer Operations Excluded*)

| | No. | Per Cent |
|---|---|---|
| Excellent | | |
| Asymptomatic | 89 | 69.0 |
| Trivial symptoms | 23 | 18.0 |
| Total | 112 | 87.0 |
| Satisfactory | 8 | 6.1 |
| Poor | 9 | 6.9 |
| | 129 | 100.0 |

TABLE VI

DUODENAL ULCER—PRIMARY RESECTIONS
ANALYSIS OF EXCELLENT AND SATISFACTORY RESULTS
(*Finsterer Operations Excluded*)

| | | |
|---|---|---|
| Symptoms referable to a small stomach | | 24 |
| Inability to eat a full meal or loss of appetite | 10 | |
| Occasional nausea after eating | 8 | |
| Discomfort or gas after eating | 4 | |
| Rare vomiting | 2 | |
| Symptoms referable to rapid emptying of stomach | | 15 |
| Exhaustion, weakness, vertigo, rapid pulse, perspiration after eating | 7 | |
| Diarrhea, occasional or persistent | 6 | |
| Lower abdominal pain after eating | 2 | |
| Symptoms of weight loss or inability to gain | | 5 |
| Symptoms of secondary anemia | | 2 |
| Symptoms of hypoglycemia | | 2 |
| Special food intolerance | | 22 |
| Fats | 5 | |
| Carbohydrates | 4 | |
| Milk | 3 | |
| Cheese | 2 | |
| Chocolate, cabbage, spaghetti, raw vegetables, citrus fruits, coffee, hot drinks, cold drinks—1 each | 8 | |
| Total symptoms | 70 | |
| Total patients with symptoms | 31 | |
| Average number symptoms per patient | 2+ | |

Three patients have been encountered in each group. Those in the last group could probably be improved by a change in domestic environment or psychotherapy, but at present they are unhappy with reference of their symptoms to the gastro-intestinal tract.

Three patients, all resected primarily for hemorrhage, have had recurrent bleeding, 3, 4 and 7 years postoperatively, respectively. In two of them the

diagnosis of gastritis has been established by roentgenologic examination and gastroscopy. They have not been subjected to further surgery, although it is possible that vagotomy might cure them.

Evidence of continued ulcer activity, following a supposedly adequate stomach resection for duodenal ulcer is, after all, the most serious type of failure. Anastomotic ulcer, reviewed by us[18] from the records of the Massachusetts General Hospital, revealed that one-third of them appeared during the first postoperative year. A second third occurred during the second year, while the remaining third was spread from 3 to 18 years after operation. For this reason,

TABLE VII

DUODENAL ULCER—PRIMARY RESECTIONS
CHANGE IN WEIGHT POSTRESECTION IN POUNDS

| | Indication for Resection | | | Average |
|---|---|---|---|---|
| | Bleeding | Pain | Obstruction | (All Cases) |
| Males | — 6 | — 7 | — 4 | — 6 |
| Females | —25 | —14 | +10 | —13 |

Weight loss in 61% of patients.
No change in 16%.
Gain in 23%.

TABLE VIII

DUODENAL ULCER—PRIMARY RESECTIONS
FOLLOW-UP RESULTS ACCORDING TO SEX
(*Finsterer Operations Excluded*)

| | Males | | Females | |
|---|---|---|---|---|
| | No. | Per Cent | No. | Per Cent |
| Excellent | 95 | 90.5 | 17 | 71 |
| Satisfactory | 3 | 2.9 | 5 | 21 |
| Poor | 7 | 6.6 | 2 | 8 |
| Total | 105 | 100.0 | 24 | 100 |

we realize that there is still time for many of our cases now classified as excellent results to develop this late complication. Although jejunal ulcer has occurred rarely in our series, we are impressed by the complete lack of symptoms for ten years in one patient, who has recently appeared with a large anastomotic ulcer. This man has been spectacularly relieved for the time being by transthoracic vagotomy. A second patient, who developed a jejunal ulcer, was relieved by a higher resection, and the third by excision of the antral segment.

We can easily explain the development of early anastomotic ulcer on the basis of antral mucosa left *in situ*. Since two-thirds of these cases occur within the first two years after operation, it seems reasonable to suppose that a technical fault in the procedure should be looked for. We have already described the difficulties met in removing all antral mucosa from a distal segment of

stomach left for closure. We believe, however, that all the antral cells, which so often extend high on the lesser curvature, are not included in many resections. It is interesting to note that the specimens of stomach removed average 11 cm. in length on the lesser curvature in the most successful cases. If the same area measures less than 10 cm., anastomotic ulcer may occur. We have frequently been impressed by the narrow margin of safety seen in our own specimens.

We believe that the anastomosis between the proximal stomach segment and the jejunum should be made as near the duodenojejunal junction as possible. This is based on a few instances of early unsatisfactory experiences with antecolic anastomosis. Lannin[19] in Wangensteen's Clinic brought experimental and clinical evidence forward to support posterior short-loop anastomosis. In that

TABLE IX

DUODENAL ULCER—PRIMARY RESECTIONS
ANALYSIS OF POOR RESULTS

(*Finsterer Operations Excluded*)

| | No. |
|---|---|
| Anastomotic ulcer | 3 |
| One, 2 years postresection—secondary resection | |
| One, 10 years postresection—vagotomy | |
| One, 1 year postresection—treatment elsewhere | |
| Postoperative hemorrhage | 3 |
| One, 7 years postresection—diagnosis gastritis | |
| One, 4 years postresection—diagnosis gastritis | |
| One, 3 years postresection—treatment elsewhere; no diagnosis | |
| Severe postresection symptoms | 3 |
| Two, nausea, vomiting, marked loss of weight | |
| One, intolerance to food, palpitation, weight loss, avitaminosis | |
| Total poor results | 9 |

clinic it has been demonstrated in laboratory animals that the incidence of anastomotic ulcer is increased by each additional few centimeters of the small intestine proximal to the anastomosis. This ranges from zero at the duodenojejunal junction to 100 per cent in the terminal ileum. There are in other clinics large groups of patients available for study who have had antecolic anastomosis following subtotal gastrectomy for duodenal ulcer. It will be of interest to compare the groups of patients who have had antecolic and postcolic anastomoses when all these data are available. It should be remembered that anastomotic ulcer is not a sequel to gastro-enterostomy following stomach resection for gastric ulcer. It is hoped that authors will bear this in mind in reporting their results, and that duodenal and gastric ulcers will be reported in separate groups.

It is by further follow-up studies that a true evaluation of subtotal gastrectomy for duodenal ulcer can be made. It may be that we have deluded ourselves regarding this procedure. Such an opinion has long been held by Heuer,[20] and others. It has always seemed probable that a more satisfactory and less radical method of dealing with duodenal ulcer than subtotal gastrectomy would eventually be found. We are certain that the results obtained are more nearly

satisfactory by this method of surgical approach than those by any other that we have tried. We believe, however, that such a procedure may not be quite so good as we had hoped for when considered from every angle. A more rational approach to this derangement of physiology may well be found. Transthoracic vagotomy as advocated by Dragstedt may prove to be the best answer to the problem at this time.

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DISCUSSION.—DR. LESTER R. DRAGSTEDT, Chicago, Ill.: I have been very much interested in this critical analysis of results obtained in the treatment of duodenal ulcer by subtotal gastrectomy. It seems to me it is well worth while to make such a critical evaluation of the present status of this operation at this time because, as Doctor Allen has so generously stated, we have now available an alternative method. During the past three years I have sectioned the vagus nerves to the stomach in 67 patients with peptic ulcers of various types—duodenal, gastrojejunal and gastric. The

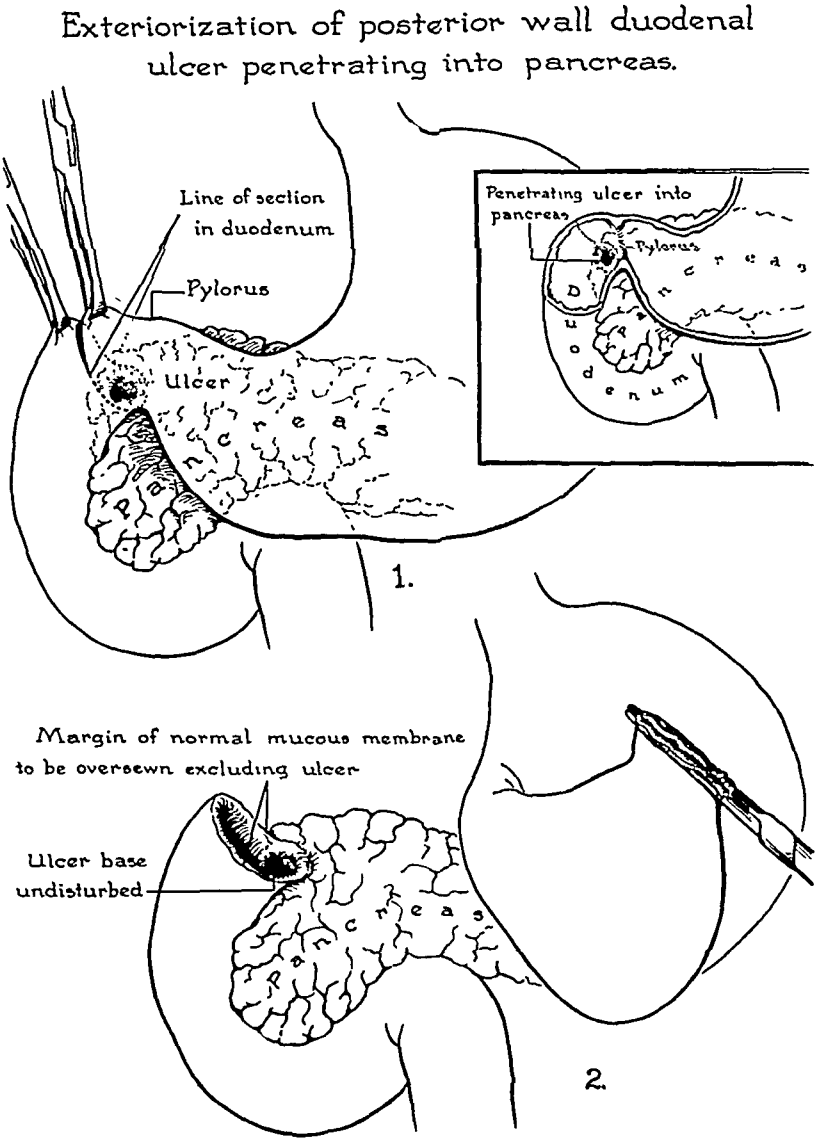



FIG. 1

results so far have been so satisfactory that I think there is a real possibility that it will replace subtotal gastrectomy in the treatment of this disease. In order to make such a decision, it is important to get postoperative data on patients who have had subtotal gastrectomy. I refer particularly to the nutritive status of the patients who have lost so important a digestive organ as the stomach. I have long felt that this is too disabling an operation for a benign lesion.

DR. ROSCOE R. GRAHAM, Toronto, Ont.: We are indebted to Doctor Allen for many things, not the least for his critical analysis of the results of his operative therapy for duodenal ulcer. There is the hope that not many years hence a gastric resection for duodenal ulcer may be replaced by more rational therapy. Doctor Dragstedt's work is indeed stimulating. The hazard of a gastric resection for duodenal ulcer centers largely about the closure of the duodenum. I should like to present a method of closure of the duodenal stump in difficult penetrating posterior wall ulcers by exteriorization of the ulcer base. The duodenum is adequately mobilized and the

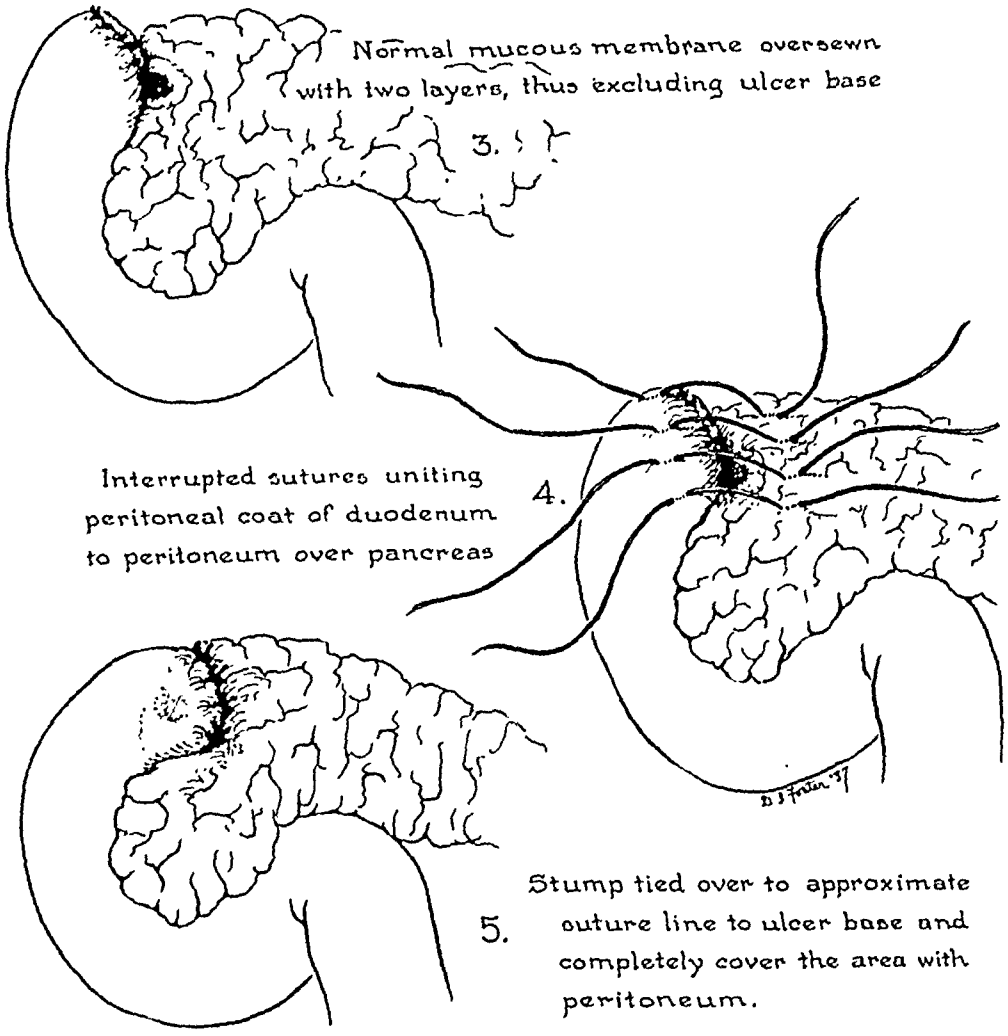



FIG. 2

common bile duct is visualized. The duodenum is then boldly opened and divided so that all the mucous membrane on the medial side of the ulcer is removed (Fig. 1). No effort should be made to separate the lateral side of the ulcer base from the posteromedial quadrant of the duodenal stump. Not only is this unnecessary, but attempts to do so produce not only hemorrhage but gross tissue trauma. The duodenal stump can then be closed without tension, leaving the ulcer base outside the lumen. The closed stump is then held against the ulcer base by sutures which unite the peritoneum over the pancreas with that on the lateral side of the duodenum, thus, completely retroperitonizing the closure (Fig. 2). This has given us happy results.

Doctor Allen has mentioned one of the unexplained syndromes following gastric resection; the patient who, after a meal, usually breakfast, becomes nauseated, pale, sweating and weak. These distressing symptoms are relieved by recumbency, and rarely last longer than half an hour. The roentgenologic study of such patients with a barium meal showed that in the early group where we had made a large stoma, there was a reflux of gastric contents into the proximal jejunal loop. We now make a small stoma and suture the proximal jejunal loop up on the stomach so that there is formed a valve. The entrance of the proximal jejunum is at a much higher level than the efferent jejunal loop. This was originally suggested by Finsterer to further secure the gastric suture line. While this technic has not eliminated this postoperative syndrome, it has become much more infrequent.

DR. G. GAVIN MILLER, Montreal, Quebec: The subject of subtotal resection for gastroduodenal ulcer covers a wide field, and I would like to restrict myself to only one point, namely, the question of nutrition. In a definite percentage of cases who have undergone resection, weight-loss, weakness, anorexia, and occasionally dizziness and nausea persist. Blood sugar curves show an early and high rise to 200, or even 300 mg. per cent, followed by a rapid fall, so that in two or three hours the level may fall to 50, or even lower; I have seen the late levels fall to 35. If, however, the patient is brought into the hospital and given an adequate diet for three days the blood sugar curve becomes normal. This emphasizes the importance of nutrition in the symptom complex which develops in about ten per cent of patients following resection. This group are usually nervous and apprehensive, have anorexia, are afraid to eat. In the hospital we can, by the use of casex milk shakes and adequate diet, overcome these symptoms. Great emphasis must be laid on their food intake; they should be on a high protein diet and should eat something every two hours. In this way we can greatly help, if not entirely overcome the problem. Postresected cases who enjoy their food, eat everything in reason, and gain weight, never have these symptoms. For this reason I never limit the diet following resection except to warn against foolish excesses.

DR. FRANK H. LAHEY, Boston, Mass.: Subtotal gastrectomy has, on the whole, been such a satisfactory operation for duodenal ulcer over a period of years adequate to give it a thorough trial, that we must be careful not to relinquish it for one that is as yet really not demonstrated.

Vagotomy in certain cases offers real promise, but with its two as yet undemonstrated effects: (1) loss of motility particularly in patients with duodenal ulcers of an obstructive character; and (2) the uncertainty of the effect of vagotomy done below the diaphragm, we must wait and assess its value carefully before substituting it for the now quite well proven procedures.

We feel very strongly that the technical problem in subtotal gastrectomy for duodenal ulcers is not in the subtotal gastrectomy itself but in the removal of the ulcer. We have repeatedly said that we like to get the duodenal ulcer out because the patient is better off with it out, but particularly because it provides then a good flexible duodenum for safe inversion. Duodenal ulcers so scar, shorten and indurate the duodenum that in many cases if the ulcer is left behind the duodenal closure will be far from a safe and satisfactory one.

Some time ago I suggested that in those cases in which the duodenal ulcer is adherent to the common bile duct, an identifying T-tube be put in the common duct and passed into the duodenum, so that the point of entrance of the common duct into the duodenum and the relation of the ulcer to the common duct could at all times be demonstrated, and that has been, in the very difficult cases, a procedure of real value to us.

I am pleased that Dr. Roscoe Graham has a favorable opinion of the so-called hook-up procedure, the Hofmeister type of subtotal gastrectomy which we have employed over the years. Our Gastro-enterologic Department made a study of this type of anastomosis as compared with the Pólya type of anastomosis, without informing us that they were doing so. They have reported that with the Hofmeister hook-up type of anastomosis, the stomach holds food a much longer time than it does following the Pólya type of resection.

DR. ARTHUR W. ALLEN, Boston, Mass. (closing): Probably it is unnecessary, but I should like to reëmphasize a statement that I have made before, and that is to stick to duodenal ulcer in reporting results for subtotal gastrectomy for duodenal ulcer. We must report gastric ulcer cases separately since the problems are so different.

A point I would like to make is the apparent difference in the results obtained in men and women who have had this operation. Men, although we have a larger percentage of them, are less likely to have late nutritional disturbances than women. We do not know why this is so, but women seem to have more difficulty with diet and maintenance of weight than men.

Doctor Graham's method of exteriorizing of the ulcer penetrating the pancreas is one we have tried. I have had the experience of pancreatic collections that had to be drained after exteriorizing such an ulcer. I have also had a patient develop stenosis of the transpancreatic portion of the bile duct months after operation. I have a feeling that many of these problems can be satisfactorily met if the proper operation is selected for the individual patient.

# CONGENITAL HYPERTROPHIC PYLORIC STENOSIS*

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NEW YORK, N. Y.

IN FORMER PAPERS on congenital hypertrophic pyloric stenosis published in 1932 and 1937, I reported a total of 243 consecutive cases operated upon by me at the Babies Hospital in New York with only one death. The purpose of this paper is to bring up to date my personal series of cases at the above hospital, a series which, with the 245 cases upon which I have operated with two deaths since 1937, now comprises 507 cases. We have made no important changes in the treatment, always using the Fredet-Rammstedt operation and emphasizing the immediate preoperative preparation and postoperative care. The success of modern surgical treatment, in which a cure can be permanently and easily achieved by a simple operation continues to prove its superiority over extended medical treatment with its prolonged and uncertain results. With a mortality of 1.8 surgery can be more vigorously recommended than when the mortality was 35 per cent. Parents can now be assured not only that their baby may be operated upon successfully and that he will be retaining all feedings and gaining weight 10 days after operation, but also that he will have no stomach trouble later in life as a result of his pyloric stenosis in infancy.

*Etiology.*—In spite of the many theories which have been achieved, the etiology is no clearer today than it was in 1887 when Hirschsprung presented two of the earliest cases on record. There are still many phases of the disease and its cure which are unexplained, the chief of these being whether the hypertrophy of the circular muscle precedes or follows the pylorospasm. Others are the occasional spontaneous cure, the disappearance of the tumor about seven weeks after the Fredet-Rammstedt operation, its persistence throughout life in patients who have had posterior gastro-enterostomies, the hypertrophy of the circular muscle coat, the occurrence of the condition about seven times more often in boys than in girls, and its frequency in the first child of a family.

It is our belief that the tumor is congenital in origin, that the pylorospasm follows the hypertrophy and that pylorospasm is responsible for the onset of symptoms between the second and fifth weeks of life. This belief is supported by finding well-marked tumors in each of two premature infants and by the absence of correlation between the size of the tumor and the age at which operation is performed. Fully developed tumors have been found in many babies upon whom we have operated a few days after the onset of symptoms. The variation in the severity of the symptoms seems to be due rather to the amount of pylorospasm present than to the size of

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

the tumor, since the largest tumor is often present when the onset of the symptoms is least severe.

Pyloric stenosis has occurred in one of twins, the other twin being perfectly normal, and in both babies when the twins were identical. We have found it in all races and nationalities with a slight predominance in the children of Jewish parents, and we have had about two colored babies in each hundred cases. We have not been able to demonstrate a seasonal incidence.

*Pathologic Anatomy.* — Operative treatment of pyloric stenosis has made it possible to confirm the pathologic findings as described by the earliest writers. The most striking feature is the firm, almost cartilaginous, tumor found at the pylorus. This tumor, which completely encircles the pylorus, is about 3 cm. long and 1.5 cm. in diameter. It is freely movable and projects into the duodenum as the cervix does into the vagina, gradually blending into the pyloric antrum at the gastric end. The term "scirrhous" as applied to this tumor by the earliest writers is quite appropriate. When stimulated, the tumor becomes blanched and firmer in consistency, and when the circular muscle is cut, it is found to be 5–10 mm. in thickness. The stomach is normal except for compensatory hypertrophy and dilatation. Cross-section reveals the lumen of the pylorus almost completely closed and the hypertrophy confined to the circular muscle coat. Microscopic study confirms the site of the hypertropy, and shows all other structures to be normal. The pathologic anatomy in cases of long-standing does not differ from that in cases of short duration except that the stomach is hypertrophied and dilated to a greater degree.

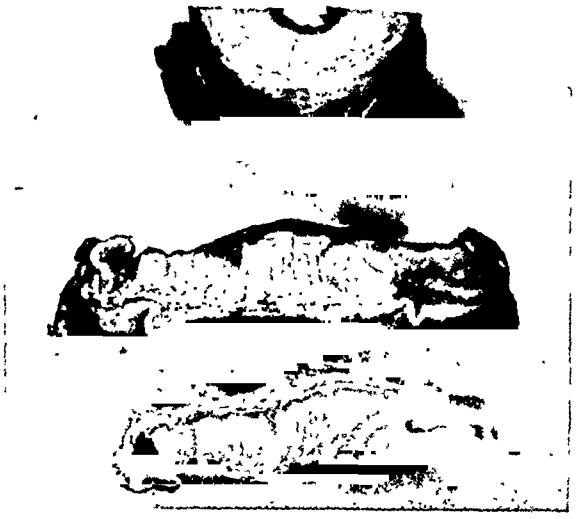


FIG. 1.—Pylorus removed in a patient 29 years of age. Gastro-enterostomy performed in infancy for pyloric stenosis. Pylorus looks much the same as these tumors do in infancy. Microscopic section shows only hypertrophy of the circular muscle coat; width 5 cm.

*Clinical Course.*—The clinical picture of pyloric stenosis is impressively uniform. Vomiting during or after each feeding is always the first symptom. It may start abruptly, but it usually begins as a regurgitation. The quantity vomited may be small at first, but it increases later, and it may amount to considerably more than the previous feeding due to gastric secretion and to the ever-present gastric retention. The vomiting soon becomes projectile and forceful enough to eject the stomach contents several feet, but it cannot be painful or accompanied by nausea since a complete feeding will often be taken immediately thereafter. The vomitus is never bile-stained, but it may contain mucus and bright blood or coffee-ground material resulting either

from the associated gastritis or from the rupture of a mucosal vessel during the act of vomiting. The baby may lose enough fluid by vomiting to become extremely dehydrated, to lose weight rapidly, to be constipated and to pass only small amounts of concentrated urine.

The course of pyloric stenosis is liable to be rapidly progressive; it is not unusual for these babies to lose from 30 to 50 Gm. in weight daily if the condition is not recognized and treatment instituted. If fluid is not restored, one may expect death from dehydration and starvation in about four weeks' time. Occasionally one sees a baby in whom the progress of the disease is much slower even though the tumor is well defined, and it is in this type of case that medical treatment may be successful.

*Diagnosis.*—The diagnosis depends entirely upon a history of the course as described and upon palpation of the pyloric tumor which is present in every true case, and which is pathognomonic, being found in no other condition. Gastric peristaltic waves, although always present, their intensity depending upon the duration of the obstruction, cannot be considered diagnostic since they occur in other conditions. The waves start at the left costal margin and pass across the epigastrium toward the right side. It is not unusual to see a second wave start before the first has completely disappeared. In a long-standing case, in which there has been a considerable loss of weight, the waves are easily seen, and the outline of the full stomach is sometimes evident through the thin abdominal wall. While waves are most obvious after the baby has had a feeding or when the stomach is full, the tumor is felt most easily when the stomach is empty and the baby is relaxed with a sugar pacifier. As we believe that the tumor can be felt in every case, we do not operate until it has been felt. If some such rule is not established, many patients will be operated upon who do not have pyloric tumors. The tumor, which feels like a small olive, is found most frequently in the right upper quadrant to the right of the lateral border of the rectus muscle and about 4 cm. above the umbilicus. If the tumor lies beneath the liver or the right rectus muscle, it is difficult to feel, and a bulge of rectus muscle between the linea transversa may be mistaken for it, particularly if the abdomen is not well relaxed. If one presses the fundus of the stomach toward the midline with the left hand while palpating for the tumor with the right hand, many tumors will be brought out where they can be felt easily. The tumor may often be found at the point over the right epigastrium where the peristaltic wave disappears. It is in many instances surprisingly superficial. Although diagnosis may be made roentgenologically, we believe this to be not only unnecessary but actually contraindicated since it greatly increases the baby's postoperative discomfort if all the medium is not removed.

*Preoperative Treatment.*—Restoration of the fluid lost by vomiting before operation is, without doubt, the most important factor in the present low surgical mortality. This operation should never be considered an emergency, and no baby should be operated upon until he is completely hydrated. It is perfectly safe and often necessary to spend several days

in preparing a baby for operation. Because many of these babies have alkalosis with a chloride deficiency, saline should be supplied in generous quantities. Hypodermoclyses consisting of about 80 cc. of physiologic salt solution with or without dissolved glucose should be given twice a day until hydration is complete and this point may be determined by clinical observation rather than by laboratory tests. Transfusion of blood and intravenous fluids are practically never necessary. During the days of preparation, the baby should be given 60 cc. of 5 per cent glucose by mouth every three hours since he retains this better than a formula feeding.

*Immediate Preoperative Care.*—Three points in the immediate preoperative care which contribute materially to the success of the operation are worth emphasizing. Open drop-ether is the anesthetic of choice since it is well tolerated by these small babies. Novocaine may be used for local infiltration or field block, but we believe that it makes the operation more difficult, not only for the patient, but also for the surgeon; and it sometimes interferes with proper wound healing. Body heat may be maintained during operation by placing a half-filled hot-water bottle beneath the baby on the operating table. It is much easier to handle the stomach during operation, and the chance of opening the duodenum is decreased, if the stomach is emptied with a tube immediately before the incision is made.

*Operation.*—The Fredet-Rammstedt operation is used in all cases because it is simple to execute, and it gives a permanent result. Its purpose is to relieve the obstruction at the pylorus by incising the circular muscle and spreading the cut-muscle surfaces until the mucosa completely fills the incision. Tincture of merthiolate is used to paint the skin, and a 6-cm. right rectus incision is made, starting 1 cm. below and to the right of the xiphoid cartilage. In order to deliver the pylorus into this high incision, the liver has to be retracted upward. The pylorus is delivered into the incision and the tumor held between the left index finger and the left thumb, is incised over its entire length beginning at the pyloric vein and passing upward. Only the superficial part of the tumor should be cut with the scalpel, and the incision should not be made too near the duodenal end because of the danger of perforating the mucous membrane. The cut-muscle edges are spread with a mosquito forceps beginning at the stomach end of the incision until the mucosa bulges sufficiently to completely fill the incision. The pylorus is dropped back into the abdomen and allowed to remain undisturbed while the parietal peritoneum is picked up with forceps preparatory to the closure of the abdomen. The tumor is then exposed in the abdomen to be sure that it is not bleeding. The liver, after release of the retractors, usually walls the peritoneal incision off from the rest of the abdominal cavity, thus, practically insuring against wound evisceration. To close the abdomen, we use continuous chromic in the peritoneum and anterior rectus sheath, and Michel clips in the skin. A small dry dressing is applied with adhesive straps. The clips are removed on the third or fourth day. After having tried fine silk closures, which would seem ideal for these incisions, we have

returned to the use of chromic catgut because of the great nuisance of removing the silk knots which may be quite troublesome even when the finest material is used.

*Postoperative Treatment.*—After operation, the baby is taken immediately to the "Pyloric Room" where the temperature is kept constant and from which all visitors are excluded. These infants in particular must be protected from all sources of infection because of their low resistance.

Each patient receives a clysis of saline and glucose once a day for the first three days after operation. The formula is increased until the baby is receiving 30 cc. every three hours at the end of 24 hours. All feedings for the first five days are given with a medicine dropper; the head of the bed is usually elevated to about 20° at feeding times, but the infant is not picked up. If the baby is to be breast fed, he is nursed once on the fifth day, twice on the sixth, *etc.*, until completely breast fed. Breast-fed babies are discharged from the hospital on the tenth postoperative day, while formula-fed babies are discharged on the fourteenth day after operation.

*Complications.*—It is unusual for a pyloric baby to have anything but the most uncomplicated convalescence. If the stomach has been properly emptied in the operating room and the operation correctly done, these babies do not vomit. If vomiting occurs, emptying the stomach with a tube will usually be all that is necessary. Postoperative respiratory infections are almost unheard of. One baby in this series developed an aspiration pneumonia just as he was ready for operation, but he was operated upon successfully under local anesthesia. One patient developed a duodenal obstruction from adhesions six weeks after operation, but was completely relieved by freeing the adhesions. The duodenum was inadvertently opened twice in this series, but in neither case was the convalescence affected. There has been one wound evisceration in this group but convalescence was uninterrupted after resuturing of the incision. We have had no severe wound infections and no known incisional herniae.

*Healing after Fredet-Rammstedt Operation.*—Dr. Martha Wollstein has made a study of healing after the Fredet-Rammstedt operation based upon a study of material from twenty-three autopsies performed from 24 hours to two years after operation. A brief summary of the important points of that study follows:

After the Fredet-Rammstedt operation, healing is brought about by cells of the serosa and submucosa, but the unstriped muscle cells take no part in the process. The incision in the pylorus is healed in nine days. The pylorus has become relaxed within two weeks. The stomach has returned to normal size within a month and the gap between the cut ends of the muscle coats has practically disappeared in six weeks. In two years only a thin line of connective tissue fibers separates these two muscle ends and the stomach is quite normal. In contrast to the operation of gastro-enterostomy which leaves the pylorus unchanged, the Fredet-Rammstedt operation cures the pylorus lesion.

*Follow-up.*—We have been able to follow 82 per cent of our cases. The two deaths in this series of 245 cases (1937–1946) may be briefly summarized as follows:

The baby died one month after operation from enteritis from which he was suffering at the time of operation. After operation, his vomiting ceased, but his diarrhea continued until his death. At autopsy, the Fredet-Rammstedt operation was well healed, but a severe enteritis was present, the cause of which was undetermined. He also had multiple congenital anomalies. The second baby died very suddenly 12 hours after operation. The only relevant contributing cause was a very stormy anesthetic with difficult and prolonged induction. No autopsy was obtained.

I have operated upon two patients, 29 years of age, who had had gastro-enterostomies performed at the age of six weeks for pyloric stenosis. In both patients, the pyloric tumor was present, looking exactly as it does in infancy. Microscopic study of one of these tumors showed that the only abnormal finding was hypertrophy of the circular muscle coat.

## SUMMARY

1. Congenital hypertrophic pyloric stenosis occurs about seven times more often in boys than in girls.

2. Vomiting is always the first symptom and in the majority of the cases begins between the second and the fifth week of life.

3. The tumor, caused by hypertrophy of the circular muscle of the pylorus, is pathognomonic of the condition and may be felt in every case.

4. The Fredet-Rammstedt submucous pyloroplasty is the most satisfactory operation and gives a permanent result, as shown by the follow-up of the cases reported.

5. Preoperative preparation is the greatest factor in bringing the mortality to its present level.

6. The tumor disappears in about seven weeks after the Fredet-Rammstedt operation but persists throughout life in those cases who have had a posterior gastro-enterostomy done.

7. Results in 507 consecutive cases are reported.

TABLE I

| No. | Deaths | Mort. % |
|---|---|---|
| 1932—119 | 7 | 5.9% |
| (100) | (1) | |
| 1937—143 | 0 | 0 |
| 1946—245 | 2 | 0.8% |
| — | — | — |
| Total 507 | 9 | 1.8% |

TABLE II

| M. | F. | Deaths | Mort. % |
|---|---|---|---|
| 1946—206 | 39 | 2 | .81% |
| Only Child | White | Colored | F.U. |
| 130 | 241 | 4 | 82% |

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DISCUSSION.—DR. WILLIAM E. LADD, Boston, Mass.: I think Doctor Donovan should be congratulated on his paper and results. His ideas so closely coincide with mine that it is rather difficult to discuss his paper. Recently we have analyzed our records, and I think a report may be of interest. This analysis differs from Doctor Donovan's in the fact that it goes back many years further, and includes cases operated upon by all the surgical staff of Children's Hospital, including the resident staff, from 1915 to 1946, a period of 30 years. In that time we have had 1,145 cases. In the first 20 years, 1915 to 1935, there were 588 cases, with 35 deaths, a mortality of 5.9 per cent. In the last ten years there were 557 cases, with five deaths, a mortality of 0.8 of one per cent. In the last three and one-half years, there have been 225 consecutive cases with no deaths.

Of the five deaths in the last ten-year period, four had postmortem examinations. The causes of death were as follows: The first, aspiration pneumonia; the second was a questionable Mongolian idiot with defects of the central nervous system, kidneys and ureter; the third, pulmonary edema and terminal pneumonia. (I think this was possibly due to giving too much fluid. One should be cautious about not giving too much parenteral fluid to these small babies.) The fourth case died apparently of intestinal obstruction from congenital stenosis of the ileum which was not recognized at the time of the operation for pyloric stenosis.

I want to congratulate Doctor Donovan on the incision. We had more trouble with wounds in the first part of our series than he did. We had a few eviscerations and a certain number of cases in which the wound broke down. That may have been due to faulty technic, but I am inclined to think it was due more to the fact that in the early period we received these patients in very emaciated condition, extremely dehydrated, with extremely low resistance. We used the right rectus incision, and catgut for sutures. When we had trouble with the wounds we shifted to silk, and still had just as much trouble. More recently, we have come to the high transverse gridiron incision, and have gone back to silk. This incision gives a very good exposure and, with that and the use of silk, we have had no trouble with the wounds. I will not say that we have not had an occasional stitch that has spit-out, but not

enough to be embarrassing—and I am very easily embarrassed. I loathe having wounds spit-out stitches for any length of time.

I would put the importance of results in this order: First, recognition by the pediatrician that pyloric stenosis is a surgical condition. As long as there are no pediatricians here, I might say it took them an extremely long time to discover that. Second, recognition by the surgeon that this is not an emergency operation. I think this is extremely important. I can remember the time when we did consider it an emergency, and the worse the patient's condition the more emergent we considered it to be. Now, the worse the condition of the patient the longer we take to prepare him for operation. The third item is improvement in surgical technic and the avoidance of mistakes, which I have made and which I think most of us have made.

DR. EDWIN M. MILLER, Chicago, Ill.: I feel almost like apologizing for making any remarks, in view of the large series of cases reported by Doctor Donovan and that commented on by Doctor Ladd. However, in my personal series of 67 Ramstedt operations there have occurred several interesting things, a few of which are worthy of mention.

In making a diagnosis there is one condition which may simulate very closely the clinical picture of pyloric stenosis: *i. e.,* congenital atresia of the first part of the duodenum. Ordinarily, of course, such an anomaly occurs below the ampulla of Vater and, therefore, the vomiting of bile is a differentiating point, but occasionally one sees the atresia close to the pylorus. One of my earliest cases (1921) was of this type. The diagnosis of pyloric stenosis had been made by a prominent pediatrician in spite of the early onset of vomiting, but at operation I found a normal pylorus and side-tracked the atresia by a posterior gastro-enterostomy. That little infant (weighing about five pounds) is now a healthy young lady who recently graduated from high school.

In my series one infant was premature (seven months); another was unusual in that three months time had elapsed between birth and the onset of symptoms of pyloric obstruction. A large tumor was found at operation and the postoperative course was excellent.

We differ a little from Doctor Donovan in choice of anesthesia, finding local anesthesia very satisfactory in the vast majority of cases. In 1930 an unusual complication arose which deserves a word. The infant did well following operation for nine days, gaining weight and taking food well, but suddenly a complete block apparently occurred at the pylorus, with projectile vomiting, rapid loss of weight, and marked dehydration. I considered exposing the site of the Ramstedt procedure, but finally changed my mind, entered the abdomen on the left side and performed a posterior gastro-enterostomy. The accompanying two lantern slides show (1) the emaciated appearance of the baby just after the second operation; and (2) the plump, well-nourished infant seven weeks later, and testify to the wisdom of the procedure adopted.

DR. EDWARD J. DONOVAN, New York City (closing): There was one baby in the earlier series that I reported, upon whom a Fredet-Ramstedt operation was done, but she continued to vomit. We were able to treat her conservatively for four weeks because she was not losing weight. I then did a posterior gastro-enterostomy, with complete relief of the vomiting. At the second operation the Fredet-Ramstedt incision looked perfect, but we did a gastro-enterostomy because we suspected that some other condition existed such as a duodenal membrane which was neither visible or palpable at the time. She has remained well for several years. I wish to thank Doctor Ladd and Doctor Miller for their discussion of my paper.

# LATE RESULTS IN THE TREATMENT OF ULCERATIVE COLITIS*

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IN ORDER to determine the advisability of continuing radical surgery in the treatment of ulcerative colitis it seems wise at this time to review and to evaluate our late results. In previous communications, morbidity, immediate mortality and early results have been discussed. Many interested in this field of surgery have frequently asked what has become of these colectomized individuals after five years.

During the past ten years at the Roosevelt Hospital, we have operated upon 97 individuals with this disease; four others were operated upon in other hospitals, making a total of 101. Within the past few months I have been able to see personally, question and examine 50 of the 80 patients who survived operation and who could be reached for interview.

Following is a distribution of the cases according to the length of time since they were operated upon (Table I):

TABLE I

DISTRIBUTION OF CASES ACCORDING TO TIME SINCE OPERATION

| | |
|---|---|
| 3 operated upon | 10 years ago |
| 6 operated upon | 9 years ago |
| 4 operated upon | 8 years ago |
| 3 operated upon | 7 years ago |
| 5 operated upon | 6 years ago |
| 3 operated upon | 5 years ago |
| 7 operated upon | 4 years ago |
| 8 operated upon | 3 years ago |
| 8 operated upon | 2 years ago |
| 3 operated upon | 1 year ago |

Although the study of 50 of these patients is not a large number, there is much of importance which we have learned from this follow-up.

The most significant and encouraging fact as regards radical surgical management, in my opinion, is that 95 per cent of those individuals have gained considerable weight, are relieved of annoying bloody diarrhea and are afebrile. They have gained from 40 to 50 pounds following ileostomy and they have continued on in gaining weight up to as much as 120 pounds following removal of their colons. The average amount of weight-gain for these 50 patients is 45 pounds. There has been one striking exception in a woman of 34 to whom we gave an ileostomy and subsequently removed her entire colon and her rectum. At no time following those three procedures, nor at the present time (eight years later), has she been able to gain much weight. The over-all gain in weight has been only 16 pounds.

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

Coincident with the considerable gain in weight there has been a feeling of well-being and a remarkable mental adaptability to the nuisance of ileostomy. In questioning these patients carefully we have found them relatively content with going on with ileostomy rather than taking the chance of ascending small bowel involvement with fatal outcome (of which there is a possibility), if the ileostomy is taken down and the fecal stream restored by joining it to the upper rectal segment which has remained. Many state that they have become quite used to handling the ileal flow, both day and night. There have been no suicides in the 80 patients who have survived the operation, as far as I can learn.

In two individuals we have been able to successfully take down the ileostomy and restore the fecal stream by ileosigmoidostomy. A man, age 21, had been given ileostomy; two years later, colectomy; three years later the ileostomy was taken down, with complete reëstablishment of the fecal stream. The remaining segment of lower sigmoid and rectum had completely healed. This man made an uneventful recovery, has gained 30 pounds in weight and is perfectly well. He has two bowel movements each day, well-formed and normal in every particular. Another man, age 22, was subjected to ileostomy two years ago, colectomy one year ago; and four months ago the ileostomy was taken down and ileosigmoidostomy, side-to-side was performed. In this early follow-up the patient seems well, has gained some weight. He did have, however, a distressing diarrhea, with six to eight bowel movements a day for one month following restoration of the fecal current.

An annoying, frequent and, at times, serious complication is prolapse of the ileostomy. This has often caused a sudden obstruction to the ileal flow, either temporary or persistent. In many instances ileostomy revision had to be carried out, principally to relieve obstruction, or to prevent gangrene of the protruding intestine. However, occasionally for the reason that the stoma protruded so far and hung down to such a degree that it became disabling. We have attempted in every way to overcome this threat to the individual. We have sutured the rent in the mesentery with great care to the undersurface of the anterior abdominal wall. We have sutured as much as possible of the fatty mesentery of the ileum to the peritoneum; we have turned down a flange of serosa around the entire circumference of the ileum and sutured this to the peritoneum; even with the finest needles and suture materials; small pinpoint openings resulted through which the fluid ileal contents seeped out and escaped down the surfaces of the thigh, especially at night. In my opinion, this problem of frequent prolapse of the ileum has not been solved, and remains an unpredictable and serious complication. In one instance, nine years after ileostomy and colectomy, we have had an amazing ten-inch prolapse of the mucous fistula of the upper end of the distal divided rectal segment through the anterior abdominal wall. We have had no difficulty whatsoever from retraction of the ileal stoma back into the abdominal cavity.

Of the 38 individuals in this series with ileostomies there were 11 who

had real difficulty with prolapse; troublesome because frequently it was reduced after many hours of strenuous effort. Five of these 11, almost 50 per cent, came to revision on account of obstruction.

Aside from prolapse of the ileostomy, the greatest problem for these patients to solve is prevention of irritation of the skin around the ileal stoma. In this recent follow-up, we have tried to learn the best method of avoiding excoriation. It has been rather discouraging to determine just what is the most effective material to use on the skin.

Eleven of this group of 50 had ileosigmoidostomy and, therefore, did not have skin aggravation to contend with; one had been given transverse colostomy and had no irritation. Of the remaining 38, 19 had no trouble from skin vexation; eight had slight or moderate excoriation and the remaining 11 suffered considerably from this constant burning annoyance. All of the 19 patients, devoid of any irritation, used Fuller's earth or some dry dusting powder. The eight where there was slight or moderate irritation had occasionally used ointments. In the remaining 11, where there was marked irritation, all used some sort of greasy application, either zinc oxide ointment, aluminum paste or vaseline.

In view of these findings, we believe that the best and most satisfactory application to the skin is a dry dusting powder or Fuller's earth (kaolin). The skin should be bathed once or twice a day with soap and warm water and the powder or kaolin freely applied.

A never-ceasing worry is acute or intermittent ileus due to adhesions or volvulus at or near the ileostomy opening. Four patients were operated upon, adhesions were freed, the obstruction relieved; two had a volvulus about the ileum and in one the ileostomy had to be moved from the right to left lower quadrant due to two episodes of obstruction from volvulus.

Even after five years intermittent blocking of the lumen of ileum is relieved by a catheter inserted into the stoma followed by gentle irrigation.

There have been three striking instances of repeated collapse from sudden salt deprivation, on account of unexplainable abrupt and profuse diarrhea through the ileal stoma. During these episodes, the patients seem exhausted, prostrated, hollow-eyed and apprehensive. They are so fearful of these sudden relapses, that they carry with them, at all times, salt tablets. One man, a policeman who now weighs 225 pounds, experiences such an attack about once a month. He is aware of the oncoming attack and now has learned to immediately enter a hospital where he is given large doses of intravenous saline which forestalls the collapse.

All patients, at all times, are encouraged to use an abundant amount of salt in their food, in order to maintain a high sodium chloride blood level and, thus, avoid these distressing setbacks.

In approximately ten per cent of all people suffering from nonspecific ulcerative colitis the sigmoid and rectum are free of the disease. The cecum, ascending, transverse and occasionally the descending colon are involved; these patients, on the whole, are less desperately ill than those where

the disease starts in the rectum. They respond quickly and permanently to "by-passing" the fecal stream through ileum to sigmoid anastomosis.

We have performed primary ileosigmoidostomy in 11 cases. One of these patients progressed satisfactorily for a period of five years, when suddenly she started up with a profuse diarrhea, with blood, pus and mucus. She rapidly lost weight. Barium enema revealed that the ileum attached to the remaining sigmoid showed ulcerations for a distance of a foot and a half proximal to the anastomosis. It was deemed advisable to immediately take down her ileosigmoidostomy; we resected a secondarily involved ileum and gave her an ileostomy. Since that time she has been perfectly well, for a period of five years. Her lower sigmoid, colon and rectum have been left in. We had a further experience with a young woman, age 23, who had been given an ileostomy; her colon had been removed, and two years later she rapidly went downhill. The disease involved the ileum; four feet were resected; she continued with a severe involvement further up in the small bowel and finally succumbed.

It has come to our attention that four of our younger female patients have become pregnant. All four had ileostomies and their colons removed. We were fearful of what would happen to the ileal stoma and to the mucous fistula of the divided lower sigmoid segment, if the pregnancies were allowed to proceed. Therapeutic abortions were thought advisable and were carried out by the patients' obstetrician, after consultation.

We have found that practically all of the patients, who have been colectomized after ileostomy and retained their rectal pouch, have a fair amount of discharge through the anal opening two or three times a day, some only once a day and others once every other day. They describe these discharges as composed principally of mucus, usually light brown in color, occasionally streaked with blood.

Where the discharge is annoying and is of foul odor, a rectal lavage biweekly has proven helpful.

Incidentally, a few of these patients, when nervously or mentally upset complain of spasm in the remaining rectal pouch and in increased amount of discharge. One man, a Professor at a girls' college, whose colon we removed after ileostomy, found that when he went into the library where there were no toilet facilities for men he became very nervous, apprehensive, with severe pain in his lower pelvis and at the anal opening, spasm-like in character, and if he got too far into the library, he would immediately have to leave and would have frequent bloody discharges for the next six or eight hours thereafter—a striking example of psychosomatic medicine.

In this recent study of the late results an attempt has been made to determine if there is any standard diet that could be formulated whereby a patient could be assured of minimum discharge from the ileostomy opening. We have questioned closely these individuals who have had ileostomy from five to ten years, to see if they could suggest a diet which would be helpful. We have been absolutely unable to come to any conclusion as to what is the

most suitable diet for all patients with ileostomy. All of these people will tell you that they eat practically everything, except spinach, uncooked fruit; they cannot drink fruit juices, but they can drink in moderation, alcoholic beverages. Many of these patients who are allergic to milk, orange juice and eggs prior to operation find that since ileostomy and even colectomy, they still are upset when they try to include these articles in their diet. Surgeons throughout the country are continually writing in to find out if there is a standard diet that can be suggested to these patients. The answer is no; it is purely a matter of individualization. In general, we can say, that most of the individuals thrive on a full, regular diet except for minor idiosyncrasies.

All of these 50 patients were interrogated as to their present employment status. Forty were at work. The men had resumed their jobs or had gotten new ones; a few were laborers, insurance agents, a bank clerk, detective, dentist, real estate agents, *etc.* The women who had been housewives, after not too many months, had resumed full activity in keeping their homes in order and doing their usual chores of housekeeping.

It is surprising how little mechanical annoyance the ileostomy bag has proven to be. Many of the younger patients are able to play golf, baseball, some play tennis and a few even swim in the ocean.

In this group of 101 patients who were operated upon, there were three who showed malignant changes, originating in a polypus in some part of the colon. These three patients are still alive, one seven years, one five years and the other three years, after colectomy. Another patient developed a carcinoma in the remaining rectal segment, failed to notify her physician of persistent bleeding over two years time, and returned to our hospital to find the lesion inoperable. She succumbed to this malignant tumor.

L. D. Whittaker,[3] in 1937, reviewed 40 colectomized individuals who had been given an ileostomy and their colons and rectums had been removed. He found that after a period of about three months it was not necessary for the ileostomy bag to be changed at night, and he observed that the ileum assumed a function of the colon and enlarged after removal of the entire colon and especially the rectum; there was no marked disturbance in mineral metabolism; and that after ileostomy the chlorides and the blood plasma and serum calcium were only temporarily reduced. In other words, the ileal stoma and its adjacent segment seemed, in part, to take on some of the characteristics and function of the rectum, after prostatectomy. In our own series 11 rectums were removed following ileostomy and colectomy. In seven of these cases there was a noticeable thickening of the ileal contents and all of these patients had less difficulty at night.

Furthermore, three of the younger age-group who, due to the severity of the disease, showed lack of skeletal development prior to diversion of the cecal flow, present some improvement since. Removal of the large bowel and rectum, with ileostomy for many years, has not retarded or hindered, the normal development of the muscular, cardiovascular, skeleton or hema-

topoietic symptoms to any degree, as far as can be determined by known clinical and laboratory methods. Personality defects exist and, assuredly, can be expected on account of the constant annoyance of a flowing ileal opening.

Up to the present time the sulfonamides, except perhaps for sulfathalidine, have been disappointing in the treatment of chronic intractable ulcerative colitis. Penicillin has been proven of no value. In a personal communication with Dr. Chester Keefer,[4] of Boston, I learn that although streptomycin was tried in a considerable number of patients in the army that it, too, was valueless.

Therefore, it seems to me that radical surgical measures are the only means of offering these people, when they have reached the chronic intractable stage, any hope.

In conclusion, I should like to state that of all sick people I know of no group who require more encouragement, attention and morale support from the surgeon who operated upon them; than those who suffer from ulcerative colitis, especially in the first year of ileostomy.

## SUMMARY

In the past ten years 101 patients with intractable ulcerative colitis have been operated upon. There were 20 immediate or early fatalities. Of the 80 survivors, 50 have been seen in the past few weeks and examined by the essayist.

The average gain in weight of these 50 patients was 45 pounds.

There was found to be a surprising adaptability in the care of the ileostomy.

The fecal stream has been successfully reëstablished in two patients by ileosigmoidostomy.

Prolapse of the ileum through the stoma has been a frequently disabling and serious complication. I am unable to make any constructive suggestions to avoid it.

To prevent irritation of the skin about the ileal stoma, compound tincture of benzoin, followed by generous applications of Fuller's earth, or a dusting powder of some sort, is generally effective.

Acute ileus due to adhesions or a volvulus is not an infrequent occurrence.

Sudden collapse from salt deprivation is treated by administration of large amounts of salt orally and intravenously.

In female patients who became pregnant, therapeutic abortion, after consultation, is warranted.

There is no standard diet for all patients with ileostomy. Fruit juices and leafy vegetables should be avoided.

Frequently, following the removal of the rectum as the third and final stage in the surgical treatment of this disease, the ileostomy takes on, in some degree, the functions of the rectum; the ileal contents become more solid; the lumen appears to enlarge; and the walls thicken.

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DISCUSSION.—DR. RICHARD B. CATTELL, Boston, Mass.: Doctor Cave has made a valuable contribution in presenting his experience in the treatment of ulcerative colitis. It is essential to have reports such as his to evaluate the surgical treatment of this condition. There has been criticism of the extensive surgical procedures necessary to cure ulcerative colitis and it should be stated that the only patients submitted to operation are those who cannot be managed by medical means.

Doctor Cave has been frank in presenting the postoperative complications and we must report a similar experience. We have reduced the incidence of ileal prolapse by careful anchorage of the mesentery of the ileum to the underside of the abdominal wall and by closure of the peritoneum between the ileum aand the lateral abdominal wall.

I should like to report our experience with ulcerative colitis for a similar ten-year period, 1932–1941. Eighty-three ileostomies were performed, with 12 deaths, an operative mortality of 14.5 per cent. Thirty-nine total colectomies, all of which included removal of the rectum, were carried out, as well as 15 partial or segmental colectomies. During this ten-year period, 103 patients had 226 operations, with a patient mortality of 20 per cent and an operative mortality of 9.3 per cent. Our experience has again demonstrated the seriousness of the surgical treatment of ulcerative colitis which must necessarily be carried out on poor risk patients.

If we are justified in submitting patients to ileostomy and colectomy, we must make the life of the patient our personal responsibility. The problem of skin irritation is not so great as it was ten years ago. The Rutzen bag which can be cemented to the skin has been found very satisfactory and is a practical means of avoiding all irritation of the abdominal wall. The patient who has been under our observation for the longest period since total colectomy was performed was operated upon 14 years ago. She leads a normal life and is able to undertake all the activities she carried out before operation.

DR. HARVEY B. STONE, Baltimore, Md.: With some diffidence I would like to present a procedure I have used several times in an attempt to overcome the difficulty of marked prolapse of the ileal end through the stoma. Assuming this is the original incision with the protrusion of the ileal end, a second incision is made lateral to the first, the bowel just above the stoma is folded upon itself into a U-shaped plication, the two adjacent arms are sutured, incised in a U-shaped manner, then the U-shaped closure done as in pyloroplasty. The two arms remain adherent to each other and there is a stoma between the two lumens. That may do two things; first, it forms a bulky mass immediately above the ileostomy, which mechanically opposes difficulty to the intussusception of the intestine through the open end of the ileum; second, it forms a reservoir in which there is a temporary stasis of the liquid contents of the ileum, and perhaps a period of longer absorption and a dryer stool. It has worked in the cases in which we have tried it.

DR. JAMES D. RIVES, New Orleans, La.: In a very limited experience with this disease, I have made one observation which I think is certainly interesting and possibly significant. I think all those who perform ileostomies are faced with the question

by the patient as to whether or not it would be permanent or whether the continuity of the bowel can ultimately be restored. I have observed two groups of cases from a clinical standpoint, both small and of no statistical significance. One group consists entirely of women. In these cases when the bowel was exposed at operation it appeared grossly normal, thickening was minimal and, if we had not had roentgenologic studies prior to operation we would have doubted that extensive disease existed. After the bowel was excised the inflammatory process was found to be limited to the mucosa and submucosa, with a moderate amount of edema in the outer coats. While these patients improved in nutrition after ileostomy, they continued to have a blood and mucus discharge from the rectum, even when only the terminal sigmoid and rectum were left. The loss of blood was sufficient to cause continued secondary anemia. In each of these cases total colectomy was required, even though in one case there was total defunctionization for about five years.

The other group consists entirely of men. The bowel when exposed was extremely thick and red, frequently showing white stippling that, against the red background, gave the appearance of a strawberry. It was practically identical with the gross pathologic picture of subacute regional enteritis. In these patients not only did the nutritional state improve after operation, but the diarrhea ceased completely before the period of dehydration that follows ileostomy had been overcome. One man gained 50 pounds in 60 days, and was completely relieved of all symptoms except those incident to the ileostomy. One, I closed too soon and, as a result of complications, he died; another, still has the ileostomy but is completely free of symptoms and is now working as a flight instructor. Another, after two years showed no evidence of disease, no blood in the stool, and the ileostomy was closed. He has been free of symptoms for more than a year and appears to be cured.

The fact that those cases showing the least pathologic change in the bowel will respond poorly to defunctionalization, and that those showing the most marked pathologic changes tend to recover completely under the same regimen, suggests the possibility that they might be two entirely different diseases, although the microscopic picture in the two types differs only in degree. Whether or not these are coincidences I do not know, but it would be of value if others who see more cases than I do should prove or disprove this assumption.

DR. DERYL HART, Durham, N. C.: In a limited number of our cases of ileostomy the prolapsed ileum has been anchored within the peritoneal cavity by a relatively simple procedure which has given complete relief from the prolapse. The mesentery of the terminal ileum is laid out over the posterior peritoneum in the right iliac fossa as an open fan, with the terminal ileum coming across the pelvis from left to right and extending up and out through the ileostomy opening. The mesentery is then anchored to the posterior peritoneum with mattress sutures of silk, taking care to avoid injury to the blood vessels. As one passed further from the ileostomy, the anchoring sutures were placed further and further from the intestine, giving increasing mobility at greater distance from the ileostomy. With the ileum thus anchored, prolapse is impossible.

There are two evident dangers which must be guarded against. The first is kinking of the ileum with obstruction. In addition to bringing it in along a broad arc to the ileostomy opening, a rubber tube may be left in. Also, the course of the intestine may be noted for ease of reinsertion in case the tube comes out. The second danger is leaving a band of anchored mesentery beneath which an unanchored loop of intestine may slip, with a resultant obstruction. This is guarded against by the method of anchoring the mesentery and by closing completely the space between the ileostomy and the right abdominal wall.

Perineal wounds left from the combined abdominoperineal resection heal slowly, probably because of the character of the infection. One of our patients who received

little benefit following an ileostomy and later a colectomy except for the rectum had the rectum excised despite the most extensive dissecting infection extending through the perineum and out onto the buttocks and the labia majora. She stood the operative procedure well but continued to run a daily temperature elevation, and the infection continued to spread despite every care that could be given by the staff, including the bacteriologists and mycologists. The spread beneath the skin with multiple perforations and bridges of skin left resembled in some respects the appearance seen in advanced disease in the colon. No specific types of organisms could be identified with certainty as to its etiologic significance. Many treatments were tried including those for anaerobic infections.

After a period of two years, during which she was kept alive only with the greatest effort on the part of the staff, penicillin became available, but only for patients suffering from very serious and acute illnesses. One of the interns developed a method of salvaging the penicillin from the urine of those eligible to receive it, and applied this salvaged penicillin as compresses to the surface wounds. The improvement was immediate and nothing short of miraculous. The wounds cleared-up and skin could be grafted without difficulty. The only setbacks occurred when the supply of reclaimed penicillin was exhausted, due to the lack of patients eligible to be treated with the restricted civilian supply. From this we had hopes that ulcerative colitis might respond to penicillin therapy, but subsequent results have not borne this out.

DR. FRANK R. PETERSON, Iowa City, Iowa: I should like to make the comment that three of our women patients who have had colectomies have become pregnant, have carried their babies to term, delivered normal babies and had no difficulty so far as bowel function was concerned during the pregnancy.

DR. HENRY W. CAVE, New York City (closing): I wish to thank you for this generous discussion. I have tried the suggestion of Doctor Cattell in closing off the right side in order to prevent prolapse, but have been unsuccessful. I have never made an attempt to suture the mesentery lower down in the pelvis as described by Doctor Hart. I should think that this would prove to have real possibilities. It seems to me that Doctor Stone's method, as he described it here, would most assuredly prevent a prolapse and I think it should be tried more often by the various surgeons interested in this problem. Doctor Peterson's statement is very interesting—three patients with ileostomies and colons removed who delivered normal babies. My statement in regard to this I think should be restated: "We were fearful, no doubt an unfounded fear, of what would happen to the ileal stoma and to the mucous fistula of the divided lower sigmoid segment, if the pregnancies were allowed to proceed."

Doctor Cattell has mentioned the use of the Rutzen bag and, although I have not used this bag except in one or two instances, I think it is the best one so far on the market, and I do believe it will more surely solve the problem of excoriation than anything else we have tried.

# DIVERTICULITIS OF THE COLON*

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DIVERTICULITIS, a many-sided condition, is of interest to physicians, surgeons, pathologists, gynecologists and urologists. It can be conveniently discussed under the following headings:

1. Diverticulosis.
2. Diverticulitis with spasm.
3. Diverticulitis with complications:
   - (a) Perforation.
   - (b) Sinus and fistula.
   - (c) Obstruction.
   - (d) Complicating or masking other disease.

## DIVERTICULOSIS

Diverticulosis is the term given by Case[1] to describe the findings of multiple diverticula in a routine radiographic picture of the large bowel. By definition, it is not supposed to be of any significance — an incidental discovery which it is well to record. The patient has no symptoms referable to the diverticula and the bowel peristaltic pattern is not upset in any way. Diverticula of the descending colon and sigmoid were recorded in over 5 per cent of postmortem examinations in persons of 40 years, and over, at the Mayo Clinic;[5] and almost the same figures were given for roentgenologic examinations during life by the Mayo Clinic,[6] and by Jones,[3] of Cleveland. In the University of Rochester hospitals we have recorded diverticulosis in only 27 persons by roentgenologic examination. This roentgenologic diagnosis is apparently not reported regularly in our record room. These patients had no symptoms referable to the colon and sigmoid. Nevertheless, a listing of diverticulosis had to be changed later to diverticulitis because an inflammation occurred in some of these pouches. The reverse picture was seen where, at postmortem examination, diverticulosis was diagnosed but during life the individual had repeated attacks of diverticulitis. The recovery from the inflammation had been so perfect that no trace of previous trouble remained. We have had 553 cases of diverticulosis registered in our autopsy files of 8,500 postmortem examinations. If these were corrected for age it is certain that the incidence of diverticulosis would be high in the 40-year plus group.

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

DIVERTICULITIS WITH SPASM

Diverticulitis with spasm can be diagnosed by symptoms, by roentgenologic examination, by a combination of these two (the most satisfactory method), sometimes by proctoscopic examination,[2] by exploration, and by postmortem study. The majority of cases of diverticulitis are those with spasm. In the University of Rochester hospitals we have diagnosed diverticulitis with spasm 111 times. In 81 of these patients there were typical clinical histories and physical examination findings backed up by roentgenologic evidence of multiple diverticula with irritation and spasm of the large bowel. In 24 instances the history and physical examinations were so outstanding that no reasonable doubt could remain as to the correctness of the diagnosis without roentgenologic examination. In some of these cases the patient was considered to be too ill for barium enema examination, and it was not done. In others, it was done sometime after the acute symptoms had subsided and although diverticula were shown, no spasm was demonstrated by roentgenograms. Occasionally such examination was attempted during the attack but was unsatisfactory because of poor retention of the barium or poor preparation of the bowel for examination. In two cases the roentgenograms were characteristic of diverticulitis with spasm but the patient did not register any symptoms and very little was found on physical examination. In eight cases exploration revealed that diverticulitis with spasm was the cause of the condition for which operation was undertaken on a mistaken diagnosis. In three cases inflammation and purulent discharge had been observed about the mouths of the diverticula on proctoscopic examination. Postmortem studies confirmed the diagnosis in three instances. The histories seemed typical during life but no diverticula could be visualized by the roentgenograms, though spasm was apparent. At postmortem examination years later the diverticula were found in the sigmoid segment.

In reviewing the histories of patients with diverticulitis and spasm there seems to be a definite pattern by which this inflammation expresses itself. Over and over again, a middle-aged, or older, corpulent individual who has been habitually sedentary and constipated will have a sudden seizure of lower abdominal crampy pain. This will be accompanied by increasing constipation, often ushered in by passage of several loose stools. Distention will follow and nausea, often with vomiting as well. Feverishness and chilly sensations may be mentioned. Passage of fecal material becomes incomplete and unsatisfactory—sometimes with real tenesmus. Tenderness gradually centers toward the bladder and inguinal region just to the left of the midline. Upon examination, the temperature is usually elevated and the pulse rapid. The abdomen shows distention. There is tenderness in the lower quadrants of the abdomen, most frequently to the left of the midline, and there may be a tender mass palpable in the region of the sigmoid. The white blood count is significantly elevated in many cases. Examination of the stool may not be possible if the protective spasm is effective, as it usually is. After a period of three or four days the fever subsides, the tenderness becomes less, the

spasm relaxes and the patient feels better. The physician credits the result to his restriction of diet, antispasmodic drugs and rest in bed with or without heat or cold externally, and with or without the use of small warm rectal irrigations.

The study of our cases shows that in only rare instances does this condition occur under 40 years of age. There were only two patients in the 20's. Two others gave histories that indicated a possibility that this condition was present at 17 and 20 years, respectively. There were no patients in the 30's. In the 40's there were 14; in the 50's—31; in the 60's—36; in the 70's—21; and in the 80's—7. So that the peak age-incidence for diverticulitis with spasm is from 40 to 80 years. This is a great contrast to the age-incidence for appendicitis (Chart I).

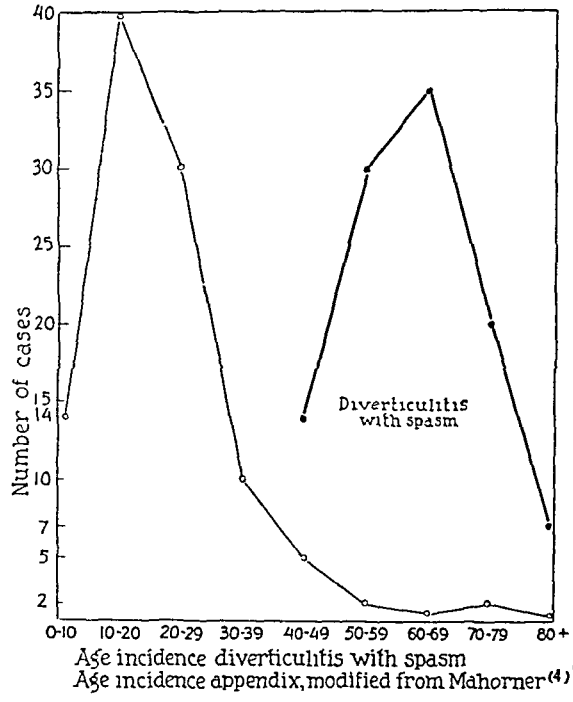



CHART I

The disease occurs about equally in males and females—61 to 50 in our series.

Pain was the most frequent symptom given in our series. It was lower abdominal, especially to the left side in 66 patients; in both lower quadrants in ten; in the right lower quadrant in five; epigastric in five; paraumbilical in three; in the left buttocks in two; in the left flank in one; and diffuse soreness in two. In the others no record is given. The pain was crampy usually, though in a few patients it was called constant. It settled in the left lower quadrant most often. Occasionally it radiated elsewhere—upper thigh in two, to testicle and penis in three; and to the costovertebral angle in three. The pain was relieved by rest, sedation, occasionally by enemas, and by bowel movements or by micturition.

Constipation (45 times) and diarrhea (37 times) were the next most frequent complaints, followed by distention (32 times), vomiting (28 times) and nausea (25 times). Slight fever was present in most patients and significantly high elevation in 29. Chills were infrequent (six times). Diminution in the caliber of the stools was noted by ten patients and tenesmus was a complaint in an equal number. Bright blood was observed 24 times and tarry stools eight times. Mucus and pus were also mentioned by a few. This occurrence of blood in the stools in 32 patients was confirmed by stool examinations. In ten of the patients there were complications, such as hemorrhoids five; rectal polypus one; rectal ulceration one; duodenal ulcer two; and gastric ulcer one, which might have accounted for the bleeding. If a correction is

made for these, bleeding was present in almost 20 per cent—a much higher figure than expected.

Other complaints of less frequency were loss of weight (22 times), bladder disturbances (12 times), weakness and fatigue (four times), loss of appetite (six times) (Chart II).

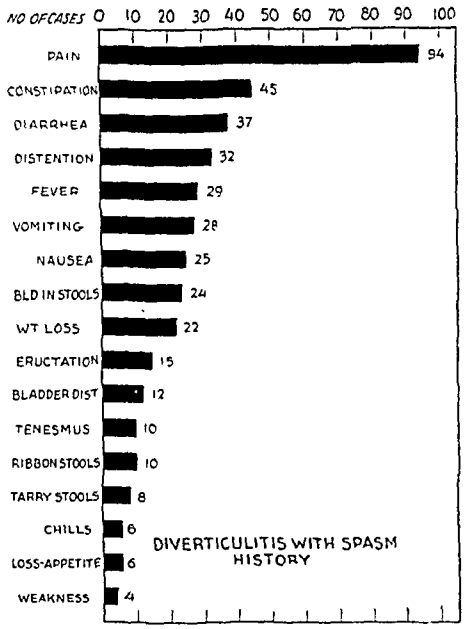



CHART II

On physical examination, many of the patients showed the degenerative conditions of age. This served to complicate the picture as some of the symptoms and signs were due to these conditions. Diverticulitis must be isolated from these diseases with their complaints and physical findings. Arteriosclerosis, arteriosclerotic heart disease, hypertension, coronary sclerosis, diabetes, obesity, arthritis, cholecystitis, benign prostatic hypertrophy, diaphragmatic hernia, *etc., etc.,* were frequently encountered in this group of patients.

The habitus of these patients was noted as obese (29 times), well-nourished (11 times), and thin (eight times). The other patients must have been nondescript or considered normal for their age-group.

Tenderness was diffuse in a large number but was noted in the LLQ (33 times); in both LQ's (13 times); in the RLQ (seven times); at McB's point (one time); in the LUQ (five times); in the CVA (three times); by pelvic examination (three times); and by rectal examination (five times).

TABLE I

DIVERTICULITIS WITH SPASM EXAMINATION

| | |
|---|---|
| Tenderness | 73 |
| Mass | 19 |
| Spasm | 15 |
| Blood in stools | 32 |
| W.B.C. over 12000 | 29 |

Spasm was infrequent, being recorded 13 times in the LLQ and twice in both YQ's. A mass was palpable 12 times in the LLQ; once in the RLQ; four times by pelvic and twice by rectal examination. Distention and borborygmi were frequently recorded. The white blood count was over 12,000 in 29 instances and occasionally reached as high as 24,000. In some of the very elderly there was no sign of fever or of polymorphonuclear response even when there was a definite acutely tender mass (Table I).

Diverticulitis with spasm is a self-limited disease. The condition will

subside or improve in three to four days to one week under good medical care. The treatment is exactly the opposite to that of acute appendicitis. The surgeon must exercise restraint during this phase of the disease.

### DIVERTICULITIS WITH COMPLICATIONS

When diverticulitis does not improve but goes over into some of the possible complications the problem is entirely different. We have encountered these complications of diverticulitis in 85 instances. In 39 of them there has been perforation, with peritonitis or local abscess. When these abscesses have been drained a fistula may result or a sinus into a dead space, or the abscess itself may burrow and open into another hollow viscus, giving fistulae of bizarre symptomatology. The wall of the infected bowel about the diverticula may harbor many small abscesses which repeatedly forming, call forth a fibrous reaction. This may lead to obstruction of the colon as may also the adhesions about a healing walled-off abscess. Finally, the diverticulitis may be complicated by carcinoma in the same area, or incidentally elsewhere, but masked by the inflammation. We have had 22 patients with diverticulitis and fistula but ten of them also had abscess, three had obstruction, one a combination of the two, and one had cancer. We have had 34 cases with obstruction but eight of them had abscess also and three had fistula and one had carcinoma. We have had 17 patients with carcinoma but two of them also had abscesses, one had obstruction, and three had fistulae.

### DIVERTICULITIS WITH PERFORATION

We have recorded 39 cases of diverticulitis with perforation. In three of them there was a perforation into the free peritoneal cavity, with extensive peritonitis. Two of these patients recovered. In one, exploration with drainage was used; in the other, cecostomy was done. Both patients received sulpha drugs. In the other 36 cases a localized abscess of considerable size was found, and drained in most instances. Twenty-four of these patients recovered and 12 died in the hospital. Two of the deaths could not be helped, due to coronary occlusion 34 days after operation and hemiplegia from thrombosis of the left posterior cerebral artery 11 days after operation. This group of patients merges into the next two groups — diverticulitis with sinus and fistula and diverticulitis with infiltration and obstruction. Eighteen of the 36 fall into these duplicate listings.

In an analysis of the symptomatology and physical findings it is at once apparent that these patients are more ill from the start or do not improve under rest and therapy. The pain is severe or knife-like in almost every instance. The pain may radiate to the back, or toward the rectum, to the hip or thigh or into the penis. It is accompanied by nausea and vomiting and distention in a majority of cases. The temperature ranges at a higher

level, a greater number being from 101.5° to 104° F. The pulse rises with the fever, the white blood counts in 20 of these patients ranged from 12,000 to 25,000. Tenderness was uniformly present, in many cases described as exquisite. It varied in localization from the LLQ to the lower abdomen on both sides and occasionally to the RLQ and the costovertebral angles. It could more frequently be demonstrated by pelvic or rectal examination than in the spastic group. Abdominal muscle spasm was noted in 41 of these examinations. Referred and rebound tenderness was also frequently elicited. A tender mass could be felt either by abdominal, rectal or pelvic examination in the same proportion. Patients complained of bladder irritation or dysuria, of increasing constipation (13 times), of diarrhea (16 times), and diminishing size of the stools (five times), and of mucus and blood in the movements (ten times), loss of weight (nine times) and loss of strength and weakness occasionally were mentioned. Barium enemas showed extravasation of barium outside the bowel lumen on three occasions and free air in the peritoneal cavity on two examinations. There were three instances where the abscess perforated into the extraperitoneal rectal space and extended into soft tissues so that it simulated an extravasation of urine with swelling and gas crackling under the skin in the region of the scrotum and penis (Chart III, Table II).

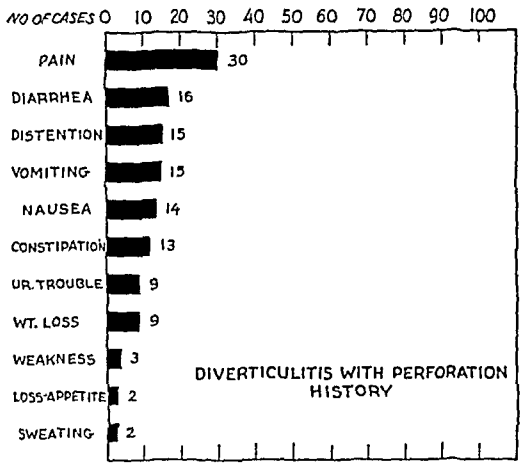



CHART III

TABLE II

DIVERTICULITIS WITH PERFORATION EXAMINATION

| | |
|---|---|
| Tenderness | 25 |
| Fever | 19 |
| Spasm | 16 |
| Mass | 16 |
| Chills | 3 |
| Ribbon stools | 5 |
| Blood in stools | 10 |
| W.B.C. over 12000 | 20 |

## DIVERTICULITIS WITH FISTULA

Diverticulitis with fistula started as an abscess which was opened or made its own way to the surface or into neighboring organs. In our 22 cases with known fistulae 11 have had the openings from the sigmoid to the skin, eight have had sigmoid to bladder fistulae, two have had sigmoid to urethra openings; two sigmoid to small intestine, one sigmoid to cecum; two sig-

moid to rectum; four sigmoid to vagina; one a sinus to the retroperitoneal tissues; one ischiorectal sinus; and one sinus into the mesocolon. In 11 cases there were more than one region involved — such as skin and bladder, *etc.* The skin had multiple fistulae in 11 instances (Table III).

TABLE III

DIVERTICULITIS WITH FISTULA

| | |
|---|---|
| No. of cases | 22 |
| Skin | 11 |
| Single | 5 |
| Multiple | 6 |
| Bladder | 8 |
| Vagina | 4 |
| Rectum | 2 |
| Urethra | 2 |
| Small intestine | 2 |
| Large intestine | 1 |
| Ischiorectal | 1 |
| Retroperitoneal | 1 |
| One site fistula | 11 |
| Multiple fistulae | 11 |

These patients may have burned out their infection in some instances so that their only complaints were the nuisance of dressing leaking fistulous openings. Those with fistula to the bladder were quite miserable with burning pain and frequency. Others had residual abscesses connected with the fistulous tracts. They had fever, loss of weight, loss of appetite and areas of tenderness. Every patient was a different problem depending on the stage of the infection, the age, and the general condition.

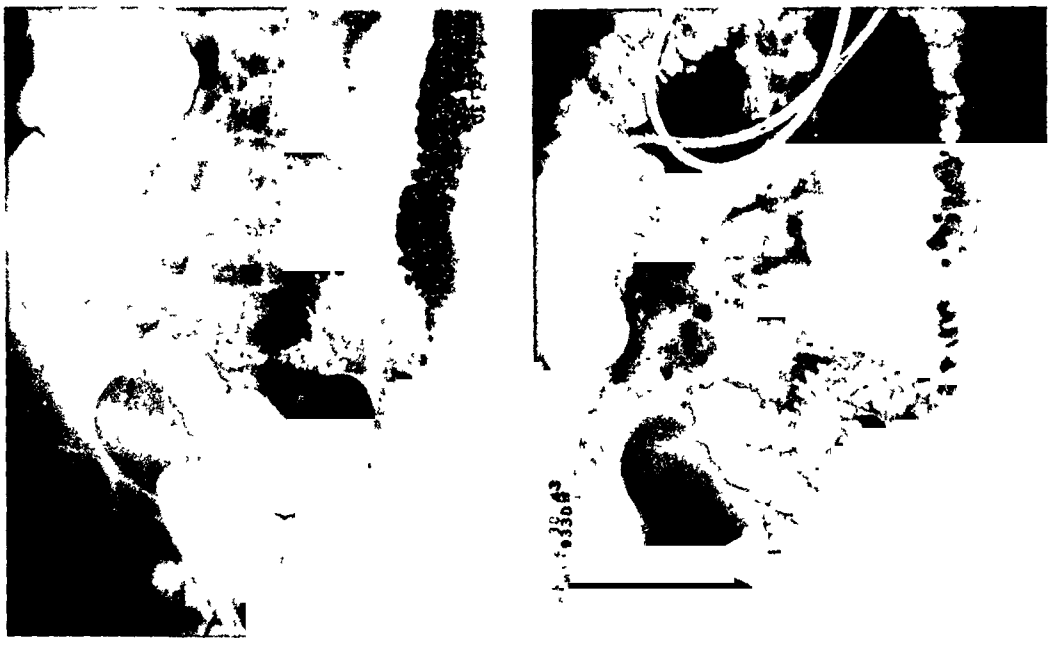
## DIVERTICULITIS WITH INFILTRATION AND OBSTRUCTION

When the descending colon and sigmoid had suffered repeated infections in the diverticula, scarring and thickening took place, resulting in a gradual occlusion of the lumen. The bowel became infiltrated with connective tissue, hard, and lost its elasticity. Other possibilities for obstruction were adhesions about an abscess cavity and adherence of the small intestine to an acutely infected diverticulum. We have had 34 cases in which there was an obstruction to the intestine. Eighteen of these were partial obstruction at the sigmoid area; 13 were complete obstruction at the same region. There were three obstructions to the small intestines which were adherent to acute inflammatory masses (Fig. 1). In one of these there was a partial large bowel obstruction as well. The problems presented by this group were many in diagnosis and treatment as well.

## DIVERTICULITIS ASSOCIATED WITH CANCER

In the group associated with cancer, the diverticulitis may have been present in a patient who has had cancer of the intestine as an incidental affair — being remote from the area. It always raised a question however. It may by chance happen that diverticulitis and cancer occur in the same place — *i.e.*, sigmoid or descending colon. Cancer of the female pelvic or-

gans may have been treated by radiation which also caused difficulty in diagnosis. In our cases there has been one cancer of the cecum, two cancers of the ascending colon, one cancer of the transverse colon, one cancer of the splenic flexure, three cancers of the sigmoid and one of the rectosigmoid junction. One patient had had cancer of the cervix treated by radiation. There were several cancers which perforated and stimulated diverticulitis with abscess. After drainage of these abscesses there was wide spread metastases within a very short period of time.



A B

FIG. 1.—A and B: No. 119330: Diverticulitis with spasm and small intestine obstruction due to adhesions to inflamed sigmoid.

## DIAGNOSIS

Diverticulitis with spasm is fairly easy to diagnose. It may be confused with acute appendicitis. When there is such a doubt, and there may be if the sigmoid lies to the right side—a simple expedient would be to give a small barium enema very carefully. If it showed spasm in the sigmoid the diagnosis would be apparent. The trouble with this in most hospitals is that the emergencies come in at off-hours of the regular roentgenologists and there is a minimum of assistance for the resident staff to get this examination made.

In diverticulitis with infiltration there is partial or complete obstruction. Often the diagnosis from carcinoma is practically impossible. Even when the surgeon has the lesion in his hand he cannot be sure whether it is a chronic inflammation or a neoplasm. The pathologist has the same difficulty until he has cut the bowel open and made a section. An intact mucous membrane of the bowel would help to settle the issue for chronic inflammation

but a recent experience with an infiltrating carcinoma (like linitis plastica of the stomach) has made even this doubtful.

In diverticulitis with complications (this includes all the rest) there are diagnostic difficulties. The women give the gynecologists many worries. The left tube and ovary frequently become attached to the inflamed sigmoid. Many of these patients received a diagnosis of solid tumor of the ovary. The



FIG 2.—No. 160625: Diverticulitis showing picket-fence spasm above the area.

gynecologist gets a surprise when he performs a celiotomy and finds the huge sigmoid inflammation. This could be obviated by careful barium enema studies on tube and ovarian masses. Another pitfall for the gynecologist is after drainage of a pelvic abscess to have a fecal fistula form. He then decides that he must have opened the intestine at some point, which does not add to his contentment. Other conditions which may be considered in diagnosis are strangulated intestine, mesenteric thrombosis and carcinoma. Extravasation of urine has been considered in some cases. There is an associated infection in the genito-urinary tract frequently noted. Pyelitis, pyelonephritis or cystitis may clear up after diverticulitis has been eliminated.

The roentgenologist makes his diagnosis of diverticulitis from the presence of the diverticula; the associated picket-fence spasm above the area (often for a good distance) (Fig. 2); the absence of chronic distention in the large bowel above the lesion; and the relatively longer segment of bowel

involved in the picture. When he cannot pass the area from below he is often unable to make a diagnosis other than obstruction of the large bowel. Occasionally he can note the characteristic nodular appearance of cancer.

Other aides in fluoroscopic diagnosis are that diverticulitis is usually tender and the bowel wall may be distensible. The lesion may be fixed, not easily movable without pain. The spasm may relax so that the picture is quite different within a week of the earlier one. Carcinoma, on the other hand, is usually not sensitive, it is rigid and nondistensible, it is firm but not fixed, and the picture remains constant.

In perforation, free air may be demonstrated in the peritoneal cavity and extravasation of barium outside the lumen may be noted. This would occur with perforation of either diverticulitis or carcinoma.

### TREATMENT

The treatment calls for good judgment and patience on the part of the physician and the patient. Diverticulitis with spasm should be treated conservatively. Expectant treatment following the lead given by the spasm of the bowel is the best. Put the patient in complete bed rest. Limit his diet to liquids; give him antispasmodic drugs — belladonna. Heat gives comfort to some, cold to others. Warm small enemas may clear the rectum and ease the inflammation. Sulpha drugs are not necessary. Small doses of phenobarbital before meals give comfort, according to Jones.

Perforation into the peritoneal cavity will result in exploration. Simple drainage may be employed, or not, depending on conditions. A fistulous opening will often result if drainage is used. Sulpha drugs should be pushed, Wangensteen suction, heavy sedation, and parenteral fluids. Transfusions should be given, as necessary, to restore blood volume and prevent anemia.

When localized abscess is present, incision and drainage is indicated. Extraperitoneal drainage should be done if possible. Care should be taken not to disturb the abscessed area any more than is essential.

For fistulae to the skin or bladder, defunctioning colostomy away from the area — in the right transverse colon, as advocated by Devine, is the best treatment in our opinion. In this clinic we divide the loop, cutting down its mesentery, and anchor each end well-separated at the extremities of a transverse incision. The inflammation in the sigmoid will either subside or go on to abscess formation. In the latter case incision and drainage may be necessary. The same procedure, defunctioning colostomy, is useful for obstructed diverticulitis where infection may be present and smoldering. Under this treatment the diseased bowel may open so that the colostomy may be repaired. But this will be after six months to one year. The defunctioned loop can be visualized by barium roentgenologic studies to ascertain its condition. If it scars-down to a narrowed lumen it will be necessary to resect it and do an end-to-end anastomosis while the Devine colostomy is still present. Then, after an adequate time for healing the colostomy openings can be brought together again. This may be done in one to two months.

This requires three operations but it is much safer when infection is still present. It avoids disastrous fistula and break-down of anastomoses done in infected areas. When infection is all burned-out, a direct attack with resection and end-to-end anastomosis is often successful in one stage.

Smithwick[7] made a splendid review of the surgical treatment in this condition in 1942. The literature since that time has contained no large series of cases. A chart of the treatment for the complicated cases, as carried out in this clinic, shows that there is very little standardization of operative procedures (Table IV).

TABLE IV

DIVERTICULITIS WITH COMPLICATIONS

| | | | | | |
|---|---|---|---|---|---|
| No. of cases | 85 | W | 65 | D | 20 |
| No operation | 9 | W | 8 | D | 1 |
| Exploration only | 1 | W | 1 | | |
| Exp. with Mick. only | 1 | | | D | 1 |
| 1 + D | 21 | W | 17 | D | 4 |
| 1 + D: Colostomy | 14 | W | 7 | D | 7 |
| In continuity | 7 | W | 1 | D | 6 |
| Obstructive | 5 | W | 5 | | |
| With release s.i. obs. | 2 | W | 1 | D | 1 |
| Colostomy only | 18 | W | 16 | D | 2 |
| In continuity | 10 | W | 8 | D | 2 |
| Obstructive | 7 | W | 7 | | |
| With release s.i. obs. | 1 | W | 1 | | |
| Res.-Anastomosis | 16 | W | 11 | D | 5 |
| Immediate | 9 | W | 5 | D | 4 |
| Delayed | 7 | W | 6 | D | 1 |
| Side-tracking | 1 | W | 1 | | |

## CASE REPORTS

CASE 1.—No. 3175: A 67-year-old professor, was first seen in the Strong Memorial Hospital on June 4, 1929. For 2.5 years he had had episodes of pain, fever, and tenderness in the left lower abdominal quadrant. Multiple diverticula had been demonstrated in the sigmoid and descending colon. For many years there had been chronic constipation accompanying and preceding these acute disturbances.

In the last year the attacks of pain had increased in frequency and severity. Tenesmus had been present during the last month. On the day before entry he had had severe pain in the LLQ. There was frequent desire to defecate with considerable colicky pain. By the next day he was quite uncomfortable. There was localized tenderness just to the left of the midline in the LLQ. There was spasm, rebound tenderness, and a tender palpable mass in the same area. The temperature had gone to 38.5° C.; pulse 120; and W.B.C. to 14,000. Conservative treatment was instituted consisting of smooth diet, small (1 pint) s.s. enema, hot compresses to the inflamed area and tincture of belladonna to relax the spasm. Under this treatment his fever declined in 48 hours, and a good evacuation was obtained by enemas. On January 18, 1931, he had a similar attack lasting three to four days. On October 10, 1932, he was admitted for another attack accompanied by bladder irritability. This lasted two days. Stools were negative for blood. His trouble cleared up without complication.

Over the next three years he had no attacks of diverticulitis but some cardiac infarction and slight rheumatic heart disease. By careful regulation of his life he avoided further attacks of diverticulitis. He died at the age of 77 from coronary sclerosis.

Postmortem study showed the descending and sigmoid colons to contain a great

many small diverticula. These had small orifices. The sacs measured 3 to 4 mm. in diameter. They were situated just adjacent to the root of the mesentery and contained fecal concretions. There was no evidence of inflammation present.

This case illustrates that there may be repeated attacks of infection in the diverticula with complete resolution of the inflammatory reaction.

CASE 2.—No. 197567: A 60-year-old woman was admitted to the Strong Memorial Hospital, October 25, 1942, with pain in the abdomen. For three days she had had generalized lower abdominal pain, without localization. On the day of admission it had settled in the RLQ. Bowels had become costive, with constant desire but small stools. There was nausea and vomiting on two occasions. No urinary symptoms. Upon examination, there was tenderness in the RLQ, slight spasm and rebound tenderness. There was no tenderness in the LLQ but there was slight rebound tenderness there also. The right CVA was tender. Pelvic examination was negative. Temperature 104° F., P. 120, R. 25, W.B.C. 8800, Urine—a trace of albumin.

At operation, the appendix did not appear abnormal. Exploration showed a hard sausage-shaped tumor in the sigmoid. It appeared to be inflamed—probably diverticulitis.

The removed appendix showed no inflammation.

Barium enema, taken on the fifth day postoperative, showed a narrowed spastic descending colon and sigmoid with small diverticula present in this area.

When a surgeon finds that there is nothing in the appendix to support his diagnosis, he should look for other causes, as in this case.

CASE 3.—No. 134598: A 56-year-old man was admitted to Strong Memorial Hospital on November 30, 1937. He had been perfectly well until the morning of admission, when he suddenly developed severe pain in the LLQ. He moved his bowels once but the pain became worse and he had passed no flatus since. There was a slight chill but no nausea or vomiting. Pain remained steady. Examination showed a moderately obese man with a pasty appearance. Temperature 39° C.; P. 118. The abdomen showed tenderness, spasm deep in the left lower quadrant, and distention. There were bilateral inguinal herniae, readily reducible. W.B.C. 20,700. A plain roentgenogram of the abdomen showed distended small bowel loop in the LLQ. The large bowel was not remarkable.

The diagnosis was thought to be secondary ileus from a pelvic abscess, perforation of a diverticulum, mesenteric thrombosis or strangulated loop of bowel. At exploration, the small bowel was dilated all the way to the ileocecal valve. The appendix was normal. Frank pus was found in the pelvis. Drains were placed and closure made. Culture showed *E. coli* and *B. aerogenes*. His temperature reached normal on the fifth day after operation. Convalescence was without incident. He had a barium enema study 21 days after operation. It showed a narrow spastic irritable sigmoid colon with multiple diverticula. He has remained in good health since discharge from the hospital.

The difficulties in diagnosis when a peritonitis is present are well shown by this patient.

CASE 4.—No. 176259: A 74-year-old woman was admitted to the Strong Memorial Hospital on March 31, 1941. Nine years ago she had constipation accompanied by gaseous distention. Her stools became smaller in caliber and she took laxatives to obtain bowel movement. Seven years ago a colostomy was performed in another hospital. One month ago she began to pass gas and fecal matter through her urethra. This was accompanied by burning pain and marked frequency. She lost 20 pounds in weight.

Examination showed a thin, tired, chronically ill person. There was marked distention of the abdomen. There were two fistulae on the left side of the abdomen. A rectovesical fistula could not be visualized but cystoscopic examination showed marked cystitis. Cystogram did not reveal the opening into the bowel, but barium enema showed an obstruction at the distal end of the sigmoid with marked irritation and diverticula. *E. coli* was cultured from the bladder and *S. albus* and *E. coli* from the two fistulous openings. She was put on sulphaguanidine. A transverse obstructive colostomy (Devine) was done on April 17, 1941. One month later she had no urinary complaints. Three months later she had gained weight. The fistulae no longer discharged fecal material. Four months later the urine was clear.

In July, 1942, she had an abscess about one of the fistulae, with some nausea and vomiting. Under compresses it drained without surgical interference. In April, 1943, she was doing nicely. The colostomy functioned well and she had no bladder complaints. She has not been seen since then.

When a patient has multiple fistulae, and especially one into the bladder, the easiest and surest way to get relief is by a simple defunctioning of the large bowel. This requires division across the lumen so that no contents can pass.

CASE 5.—No. 200303: A 44-year-old obese physician was admitted to the Strong Memorial Hospital, May 26, 1943, because of right hydronephrosis due to a stricture at the ureteropelvic junction. He had had ureteral dilatations without discomfort on two previous admissions. Shortly following the last dilatation, March 21, 1943, he developed a colon bacillus infection of the urinary tract. He was quite miserable and had a fever to 104° F. at times for two weeks following. The symptoms disappeared but he continued to have pyuria. On admission, retrograde pyelograms showed bilateral kidney infection and bladder infection with *E. coli*. The catheter to the right side was left in place to drain the right kidney pelvis. The next day his temperature became 103.6° F.; P. 140. Most of his complaints, however, were confined to the LLQ. He gradually developed lower abdominal spasm, more on the left than on the right, distention, a tender mass to the left of the midline, and a W.B.C. of 22,500. He showed a tender indurated mass by rectal examination. The infection subsided about one week under sulphadiazine and warm s.s. enemas. He was discharged on June 7, 1943. He was readmitted on August 31, 1943. For many years he had been constipated with occasional mild LLQ pain. A typical attack has been ushered in by two days of constipation, then the pain. Suddenly there would be passage of a good deal of gas followed by a bowel movement of "hard round pellets." This pain seemed to flare-up after ureteral dilatation. His most recent attack was one week ago. Barium enema showed evidence of marked obstruction at the rectosigmoid junction. The bowel was not dilated above the obstruction and there was nothing typical of a carcinomatous defect, though it could not be ruled out. By pressure, only a small amount of barium could be made to pass. He was advised to take sulphasuccinyl at home for a week and then return here for resection. He preferred to try a conservative course. He reëntered on October 8, 1943. He had not improved. Exploration showed a huge inflammatory mass occupying the whole pelvis. A transverse colostomy was done. Drainage of the abscess through the rectum reduced the fever after ten days. He discharged pus from the rectum until January, 1944. He had daily irrigation through the lower segment. He gained 40 pounds. Roentgenograms showed marked obstruction at the rectosigmoid. On July 8, 1944, he had a resection and an end-to-end anastomosis of the sigmoid colon. The gross specimen showed an extremely thickened bowel wall with dense fibrous tissue, a pin point-sized lumen, and intact mucous membrane. Hard fecoliths were present in the diverticula. Microscopic examination showed

acute and chronic inflammation. On September 16, 1944, the transverse colostomy was reunited in an end-to-end anastomosis. The patient has been well to date.

This is a complicated picture. The kidney infection and the acute infection in the diverticula were made worse by the almost complete intestinal obstruction. If the defunctioning colostomy could have been done sooner, the pelvic abscess might have been avoided. This delayed the operative procedures considerably.

CASE 6.—No. 158503: A man, age 51, was admitted to the Strong Memorial Hospital on October 16, 1939. Ten years ago he had had onset of vague LLQ pain and feeling of fullness in the rectum. This continued for 5–6 years unrelieved by any form of therapy. Five years ago he had had peritonitis from a ruptured sigmoid diverticulum. It was drained through a lower midline incision. This incision continued to drain fecal material and occasional pus since then. He has had episodes of fever with chills and sweating lasting three–four days. His diet has been soft and his bowels without trouble. One year ago a cecostomy was done and the sinus stopped draining and closed over. The cecostomy was then closed and, although he had no bowel trouble, he developed aching pains from the crest of the ilium to the midline on the left. He had pain when he lifted his left leg — the pain being referred to the left anterior thigh. He had gained weight and had not passed blood, pus or mucus in his stools.

On entry, he had a fever of 100.4° F., P. 110. He was a large obese man. The skin over his left back felt somewhat boggy. There were healed scars and a closed sinus at the lower end of the left abdominal incision. A hard sausage-like colon could be palpated, tender to pressure but slightly mobile. W.B.C. was 23,000. Barium enema showed irritability and a narrowed irregular area in the sigmoid. There was a suggestion of a soft-tissue shadow.

On conservative treatment with warm irrigations of the colon he became worse. The pain was more severe, especially along the iliac crest. There was a crampy mid-abdominal pain noted after micturition. He also had a severe crampy seizure in the left leg when there was peristalsis in the descending colon. W.B.C. remained at 23,000 level.

At operation, an incision was made along the crest of the ilium and carried down extraperitoneally. The bowel was exposed. It was hard and infiltrated. It was then exposed through the left rectus from the peritoneal side. No abscess was found but what amounted to a cellulitis of the sigmoid was present. He was put on short-wave diathermy, and ten days later an abscess drained spontaneously from the retroperitoneal incision. This incision was accordingly opened widely. His discomfort and pains disappeared. Culture showed *E. coli, Cl. welchii,* and *nonhemolytic Streptococci.* He was discharged, relieved, to his local physician after one month in the hospital. There has been no report since 1940, at which time he was healed.

This was an unusual picture, difficult to interpret. It had the appearance of psoas abscess. A cecostomy gave only a temporary type of relief as the bowel contents were never entirely diverted by this procedure. A defunctioning colostomy might have saved the extravasation into the retroperitoneal area.

CASE 7.—No. 233109: A 67-year-old woman was admitted to the Strong Memorial Hospital on June 1, 1945. She had been having dragging sensations in the lower abdomen for the last six months. She had noted some urinary frequency with burning. Her bowels had been regular, without pain or bleeding.

Two months ago a mass was noted protruding from the rima pudendi. She was an obese woman in no distress. Her examination was not remarkable except that

she had a complete procedentia with a myomatous nodule in the isthmus, moderate cystocele and rectocele. A La Forte repair with perineorrhaphy was done. Eleven days after operation she began to drain fecal material from the left angle of the incision. A diagnosis of rectovaginal fistula was made. There was a mass in the left lower quadrant with tenderness suggesting inflammation. She had a fever to 101° F.; and W.B.C. of 14,600. Ten days of treatment with sulpha drugs were given. Exploratory celiotomy showed a large mass of inflammatory tissue with the sigmoid on top of it and the bladder and left broad ligaments attached to it. There was a perforation in the sigmoid and an abscess with a thick wall. The area was drained. *E. coli* and *nonhemolytic Streptococci* were cultured from the abscess cavity. Convalescence was stormy. Transfusion and parenteral feedings and sulphaphthalidine were given. She was discharged after two months, improved.

On October 11, 1945, barium enema showed many diverticula of the proximal sigmoid, with fecal fistulae still present. She continued to drain blood, pus and fecal matter from two sinuses on the abdominal wall. She will have a defunctioning colostomy done.

This is the kind of result that gives the gynecologist grey hairs. He thinks that he has made a technical error somewhere in his work. These complicated diverticulitis cases are among the most difficult problems in surgery.

CASE 8.—No. 8178: A 65-year-old woman was admitted to the Strong Memorial Hospital on July 19, 1933. Three weeks before admission she had fever, low abdominal and rectal pains which were very severe. She had a tender mass in the pelvis on the left side. For four days she had complete obstipation, nausea, and fever. She vomited for three days and then passed gas per rectum. When enemas were given fever and pain occurred. She had symptoms of bladder irritation also. She was known to have multiple diverticula of the colon from previous studies.

On examination, she was well-nourished but showed recent weight loss. She was pale. There was slight discomfort on deep palpation in the left iliac fossa. Pelvic examination showed the uterus fixed to a hard indurated mass the size of an orange in the left side of the pelvis. Her vital signs were within normal range. R.B.C. 3,550,000, Hb. 75 per cent; W.B.C. 10,000, Blood chemistry normal. Proctoscopic examination revealed a firm fixed mass at the rectosigmoid junction and almost complete obstruction at this point. No cancerous tissue was visible. Exploration showed a 2-cm.-sized nodule in the left liver lobe. This was confirmed by the other members of the team. It seemed to be metastatic cancer. There was a mass of firm nodular tissue at the rectosigmoid junction. A loop-colostomy was made in the descending colon. No specimen was secured but a bad prognosis was given to the family. She convalesced without incident, and was discharged on October 9, 1933. Ten days later she was readmitted with pain in the lumbar region. Roentgenograms showed arthritis but no evidence of metastasis.

In January, 1934, she had good control of her colostomy. She had gained weight and strength. Irrigation of the rectal segment showed that there was a good communication with the abdominal opening. She still had a stricture there and it could not be passed from the rectal or abdominal side.

In October, 1945, she was alive, and had no complaints referable to the large bowel. At this time she was troubled with arthritis, arteriosclerosis and an early cataract. Apparently the nodule in the left lobe of her liver is an adenoma, a hemangioma, or some such benign lesion.

This patient illustrates the difficulties in prognosis when no microscopic proof is available. The family was given a poor outlook but time has proved that this was not warranted.

CASE 9.—No. 234407: A 73-year-old woman was admitted to the Strong Memorial Hospital on July 8, 1945. Eleven months ago she first noted diminution in the size of her stools, with rectal bleeding. She began to have episodes of crampy abdominal pain usually followed and relieved by small diarrheal stools. Three months ago she had barium studies which showed diverticulitis, with partial obstruction. She was treated by her physician with smooth diet and atropine. She regained some of the weight she had lost. A second roentgenologic series was likewise interpreted as diverticulitis. Upon examination she was poorly-nourished, her abdomen showed moderate distention, with borborygmi. There was no tenderness but a movable mass was easily palpable in the sigmoid region. She had no anemia. W.B.C. 5,000. Barium enema was done here. Diagnosis of carcinoma at the rectosigmoid junction was made. Proctoscopic examination showed a tender rectum and no carcinoma was visible. She was put on sulphadiazine. She was explored and a resection of the rectosigmoid area was done. An end-to-end anastomosis was made in the pelvis. The specimen showed carcinoma and diverticulitis, with inspissated barium in the small sacs. Recovery was without incident. She was discharged, healed, 16 days after operation. Follow-up, November 14, 1945, showed that she had gained 23 pounds and had had no trouble of any kind since operation.

It is not surprising that carcinoma and diverticulitis may occur in the sigmoid segment at the same time. It is frequently impossible to decide which the lesion is without the test of time.

CASE 10.—No. 227568: A 64-year-old man was admitted to the Strong Memorial Hospital on January 1, 1945. He was well till two years ago. At that time he passed black blood from the rectum on three occasions, with no other symptoms. This left him weak. Roentgenograms showed a duodenal ulcer for which he received medical treatment, with favorable response. One month ago he had slight tenderness in the LUQ. It sometimes would extend across the upper abdomen and was relieved by belching of gas. Bowel habits had remained regular but the stools were watery in consistency. For four days his temperature spiked to 100.8°–102° F. Pulse remained at 80. The abdomen was protuberant and distended. There was moderate tenderness and spasm in the LUQ. R.B.C. 3.9, Hb. 11.8 grams; W.B.C. 13,950; stool guaiac-negative. Temperature fell to normal and pain disappeared. Barium enema study was then made. Barium showed numerous diverticula of the sigmoid. Patient could not retain the barium and no filling occurred beyond the descending colon. The night following this examination he had a chill, temperature to 103° F., and he passed some frank pus and blood per rectum. Blood culture was negative. The stools showed blood on six examinations during this hospital stay. He quieted down and was discharged for medical care, with diagnosis of diverticulitis of the sigmoid with rupture of an abscess into the rectum.

Three weeks later he was readmitted to the hospital. His pain had never abated and he had had a few episodes of nausea and vomiting. The stools did not contain blood or pus. Last night he had a chill and he became distended. There was unbearable pain in both lower quadrants. His vital signs were not remarkable. He had exquisite abdominal pain and tenderness. There was marked distention and no peristalsis was elicited. W.B.C. 6,400. A diagnosis of generalized peritonitis was made. He was started on sulphadiazine and Wangensteen suction. He was transfused and given parenteral fluids. His large bowel distention became worse and it was feared that the cecum might perforate. Under local anesthesia a McBurney incision was made. Dense green fibrinopurulent exudate covered everything. It was stripped off until the cecum could be identified and a rubber tube inserted. He made good recovery and was discharged improved with the diagnosis of ruptured diverticulitis of the sigmoid and generalized peritonitis.

Three months after discharge he passed black and red blood from the rectum. He lost from a teaspoonful to a cupful per day. He became very weak, lost ten pounds. His cecostomy continued to drain. Barium enema showed filling defects in the region of the sigmoid and an obstructive lesion near the splenic flexure. Roentgenologic examination *via* the cecostomy showed marked dilatation of the transverse colon and a carcinoma close to the splenic flexure. At operation, this was a mass of adenocarcinoma which involved the mesocolon close to the stomach and invaded posteriorly into the region of the superior mesenteric vessels. It was impossible to mobilize it. Accordingly, the transverse colon was transected and the distal end turned in under continuous silk sutures. The proximal end was anastomosed to the side of the descending colon. He was much more comfortable following this procedure. He gradually became more anemic and weaker. He died at home, 11 months after his first admission.

Perforation of the diverticula into the bowel at one time and into the peritoneal cavity at another completely masked the real lesion at the splenic flexure. It was probably an advanced lesion as it was inoperable when the diagnosis was finally reached.

CASE 11.—No. 193554: A 49-year-old woman was admitted to the Strong Memorial Hospital on July 15, 1942. She had had a ruptured gangrenous appendix with peritonitis 3.5 years ago. A left broad ligament abscess developed and was drained. Numerous abscesses at times had formed in both right and left lower quadrants ever since. A perirectal abscess was treated by incision and drainage one year ago. She had had five operations altogether. Roentgenograms two years ago showed diverticula of the large intestine. She entered here because of discharge from two areas in the right lower quadrant, accompanied by pain.

In her youth she spent three months in a tuberculosis sanitarium and was discharged with "arrested tuberculosis." She had chronic right frontal sinusitis. She had frequency, urgency and dysuria at the end of micturition when the abdominal attack flared up. Slight exertional dyspnea and ankle edema were present. Rheumatic fever was considered as a diagnosis five years ago.

*Examination:* T. 37.2° C.; P. 80; R. 20. The abdomen was obese with numerous scars, McBurney, left lower quadrant, left rectus low, right flank. There were two sinus openings with minimal serous discharge in the right lower quadrant. The whole abdomen was tender, mostly so in the right lower quadrant.

*Laboratory Data:* W.B.C. 10,000. Hb. 14.7 Gm. The urine showed occasional white blood cells. Wassermann negative. Gastric analysis—free hydrochloric acid present. Barium enema—diverticulitis with spasm in the descending colon. Michel clip near ileum. Excision of scars in the right lower quadrant with the clip was done. There was pus in the sinuses; which did not appear to enter the bowel. Culture showed no growth. Microscopic examination showed acute and chronic inflammation and foreign body reaction about the clip. No tuberculosis or other pathologic picture noted. The wound healed well and she was discharged August 5, 1942.

She entered the Strong Memorial Hospital a second time, September 30, 1942, because of bleeding from the sinus in the left lower quadrant. She had a feeling of fullness in the left lower quadrant, the diameter of her stools had greatly decreased. This sinus was traced into the sigmoid, excised, and the base turned in under a purse-string. It appeared to be a diverticulitis. Culture showed no growth.

Her third entry was on January 5, 1943. Barium studies revealed a persistent narrowed area in the sigmoid, probably secondary to a peridiverticulitis. She was treated conservatively with mineral oil and atropine which gave symptomatic relief.

The fourth admission was on February 9, 1943, because she had a "bubbling sensation in the bladder" one week before and had passed gas, mineral oil and liquid

feces in her urine ever since. She presented a palpable mass in the left lower quadrant with tenderness and increased heat over the area. Her urine was clear but packed with white blood cells. Urine culture grew *B. pyocyaneus.* White blood cells 14,000. Hb. 15.2 Gm. Pelvic examination revealed a movable tender mass in the left lower quadrant above the cul-de-sac. A Devine colostomy was done and the patient put on sulfathiazole and sulfasuccidine. A diagnosis of diverticulitis of the sigmoid with intestinovesical fistula was made. She was discharged on March 13, 1943.

She came in for the fifth time on July 6, 1943. She has had "heavy pressure in the rectum" and smarting and burning on urination. After suitable preparation, July 16, 1943, a resection of the scarred area of the sigmoid with an end-to-end anastomosis was made. There were many thick adhesions about the area and it was necessary to resect 20 cm. of ileum which was damaged in freeing it. This was anastomosed with end-to-end anastomosis about 16 cm. from the ileocecal valve. Convalescence was stormy for a few days but then uneventful. *B. pyocyaneus* and *E. coli* were cultured from the urine. Pathologic section showed acute and chronic diverticulitis of the descending colon and sigmoid.

A sinus developed in the right lower quadrant and was followed into the retroperitoneal tissues of the right flank and drained on August 28, 1943. This sinus showed chronic granulation and hyperplastic squamous epithelium. She was discharged on September 19, 1943.

Her sixth admission showed the colostomy functioning well. She had a well healed anastomosis, as seen by barium enema. On this admission a sinus went through the abdominal wall into the peritoneal cavity. It was drained. There was no evidence of a pelvic abscess.

She came a seventh time because of pain in the right flank, in the right lower back and in the right hip, with radiation to the medial aspect of the right thigh. The sinus in the right lower quadrant had been draining blood. On February 9, 1944 the four sinuses were dissected out widely from the opening. One went to the iliac bone, which was intact, one to the retroperitoneum back of the cecum, one to the right upper thigh and a fourth into the pelvis. A typical blob of actinomycotic pus was identified and saved for culture and microscopic section. The tracts were packed open with vaselined gauze drains. Thread forms were seen in the gram stain but no actinomyces were isolated. The microscopic section showed actinomycosis. Actinomyces were isolated by the bacteriologic laboratory on March 3, 1944. On April 28, 1944, the peritoneum was opened and the tract traced to a cavity in back of the uterus. A No. 18 catheter was sewed in and penicillin instilled into this sinus daily and given by continuous intravenous drip as well. Over a two-weeks period 2,500,000 units of penicillin were used. She was discharged improved on May 20, 1944.

She was admitted on February 5, 1945, and had the colostomy restored by an end-to-end anastomosis. She had gained 30 pounds in weight and was an entirely different woman. The bowel functioned nicely after operation. She was discharged, March 9, 1945, without complaints of any kind.

She was seen on November 3, 1945. She was "the picture of health." There were no complaints.

This patient represented many possible causes for her fistulae. The old tuberculous history, the foreign body, and the diverticulitis with bladder fistula were possibilities which were weighed carefully. Repeated tests for fungi had been made but it was not till late that a diagnosis of actinomycosis could be supported. This apparently accounted for her tube-ovarian abscess as actinomycosis has been reported from this area in about 75 cases.

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DISCUSSION.—DR. CARL EGGERS, New York City: Doctor Morton has given us a very good idea of the entire subject, including the question of diagnosis, course of the disease, and treatment. I should like to add a few points to this. In 1939, I read a paper before the New York Surgical Society dealing with 82 cases of this condition; since then I have had 24 additional cases, a total of 106. Sixty-one were in the group of uncomplicated cases, subsiding without operation. Forty-five patients developed complications. Of these, 43 were operated upon, and two refused operation.

The operations varied a good deal depending on the indications. Some patients had an exploration done, others had drainage or colostomy or cecostomy, with or without drainage. Twelve patients had a resection performed. There were 25 perforations; 23 perforated externally, producing abscess or peritonitis, while two perforated into the urinary bladder. There were nine postoperative deaths, confined entirely to the acute perforations. This makes 36 per cent of the 25 perforations, or about nine per cent of the total. The 12 in whom resection was done recovered. There were a few late deaths from complications or associated carcinoma.

Naturally, our interest in this condition must center largely on the possibility of preventing death in the cases with acute perforation. All the other manifestations of the disease require the same careful attention as do all colon lesions. Unfortunately, we know of no definite way to prevent perforation. These patients are usually admitted as acute emergencies. Perhaps instructing general practitioners to send cases in earlier might help. Patients known to have diverticulosis should be instructed to seek advice as soon as acute symptoms develop. To some degree perforation may be guarded against by attention to the bowels and by the administration of mineral oil. In patients who have recovered from an attack of diverticulitis and who continue to have occasional pain, operation may be considered prior to a possible perforation.

Two interesting cases of this group were those with perforation into the urinary bladder. Both were known to have diverticulosis and had had diverticulitis. The chief symptom was the passage of gas through the urethra. In the first patient I separated the two viscera and closed the perforations. He made a good recovery but had a recurrence about two years later. The perforations were again closed and soft tissue interposed with good success. In the second case, a man who had perforated locally several times before and been drained, we did a resection of the sigmoid and closed the bladder opening.

DR. HARVEY STONE, Baltimore, Md.: There are two comments I would like to make on Doctor Morton's paper and on this general topic. The first concerns blood in the stool. You will recall from Doctor Morton's figures that this is one of the more frequently occurring symptoms of the disease and, as I remember, in these cases in which other sources of bleeding such as hemorrhoids might be excluded, there were some 24 patients who had blood in the stool attributable apparently to the diverticulitis

itself. So it is by no means a rare symptom of this condition. I should like to present this relationship from a somewhat different standpoint.

About three years ago I presented a paper before this Association concerning the occurrence of large hemorrhage into the bowel, of obscure origin, and of that group of 71, on protracted study, the only cause to which the bleeding might be attributed in eight cases was diverticulosis. So I think it should be borne in mind that the outstanding symptom may be sudden profuse bleeding into the bowel. Another point has just been referred to by Doctor Eggers, the relationship to bladder fistulae. Again, I want to emphasize a slightly different aspect of that. It is our custom to treat conservatively cases which we believe to have acute diverticulitis, reserving operation for complications that more or less compel it. But in two instances, during the conservative handling of these cases, the patient developed urinary symptoms, frequency, urgency, and pain on voiding. In both cases the patients were promptly operated upon, and there were found adhesions between the sigmoid and bladder but no actual perforation. I should like to draw attention to the advisability of anticipating the formation of fistulae when these urinary symptoms present themselves, and urge that as a reason for prompt operation to forestall development of a fistula.

DR. VERNON DAVID, Chicago, Ill.: I would like to take a somewhat different view about the causal relationship of diverticulitis of the colon to hemorrhage from the large bowel, as discussed in Doctor Morton's instructive paper. It would seem to me a rather questionable doctrine to go out from this Association, to regard diverticulitis of the colon as a relatively common source of hemorrhage when there is so little reliable evidence to prove it. The basis for belief is founded on dogmatic statement or because other recognizable sources of hemorrhage have not been found. It is always possible that small adenomas or nevi may be the source of relatively minor hemorrhage and it has been well-pointed out that large or massive hemorrhage may come from sources undiscoverable even at autopsy. Until definite pathologic evidence is forthcoming, I feel that we should be reluctant to place too much emphasis on diverticulitis as a source of hemorrhage, as it engenders a sense of complacency which might well lead to overlooking a small carcinoma or a bleeding polypus.

May I add another serious, but rather rare, complication of diverticulitis to Doctor Morton's impressive list, namely, pyelophlebitis, with multiple liver abscesses, of which I have seen two instances.

DR. FRASER B. GURD, Montreal, Quebec: I would like to express my appreciation of this paper, and I want to bring up one point only. It would seem that in recent years the number of cases of diverticulitis, with complications, has increased, both the obstructive type and the perforating peritonitis type. We have come to the conclusion with a fairly large number of cases, that the performance of right-side, transverse, defunctioning colostomy is the most useful procedure, whether associated with drainage in the left lower quadrant or not. It seems that one of the chief objections to the use of Devine's procedure is the likelihood of hernia complicating the after-course of such cases.

We have, in recent years, used the technic of upper right transverse incision, that is to say, an incision through the skin reaching from approximately two centimeters to the left of the midline and extending outward to slightly beyond the lateral border of the right rectus. The anterior aponeurosis covering the rectus is split in the direction of its fibers and the rectus muscle, together with the ninth intercostal nerve, is displaced toward the midline. The posterior aponeurosis and peritoneum are then similarly incised. In this way a sufficiently large opening can be obtained to permit the hand to be introduced and careful manual examination of the abdominal viscera carried out, with special reference to the sigmoid. A portion of the great omentum corresponding to that part of the right transverse colon which will be used for the

double-barreling of the bowel is then removed. After the loop of transverse colon has been pulled out of the wound, a suture of the parallel portions over a distance of at least 12 cm. has been carried out, one clamp is introduced medial to the rectus muscle and attached to the bowel. The other clamp is introduced lateral to the rectus muscle and the bowel is divided between them. The two colostomy openings are thus placed on each side of the undamaged rectus muscle. The posterior aponeurosis and peritoneum is partially closed behind the muscle and the anterior aponeurosis and skin are sutured between the two openings, which are, thus, seen to be about six or seven centimeters apart.

It is an easy matter to keep the colon clean. With lesser space between the rosettes it becomes increasingly difficult to defunction the left bowel. The fact that the left rectus is between the bowel ends makes certain that no considerable herniation can occur.

DR. JOHN MORTON, JR., Rochester, N. Y. (closing): I wish to thank all the members who so kindly discussed the paper. I used to teach students that you could tell the difference between diverticulitis and carcinoma by the fact that with diverticulitis there was no bleeding. This statement was in all the textbooks; but I notice that the textbooks now say that bleeding occurs in 20 per cent of cases. Up to the last edition of Homans' it was given as a diagnostic point that in diverticulitis you would not expect bleeding. In our cases we tried to rule out all other factors. In one case we had massive hemorrhage, as described by Dr. Harvey Stone, with the blood count down to less than 1,000,000 cells.

One of the very interesting types of perforation is that in which the perforation is extraperitoneal near the bladder. This gives the urologists difficulty in diagnosis. They think they have extravasation, with gas-crackles in the tissues about the bladder. Diverticulitis in association with infection in the kidney and ureter has been commented on in the literature, and we have had several instances. Probably one reason that this disease has interested me so much is that there have been complications in many cases. I operated upon one woman eight or nine times because she had a fistula that would not close. We resected it early, did a defunctioning colostomy later and, finally, after the seventh or eighth operation, we found that she had actinomycosis. She cleared up completely under penicillin, and is now an entirely different person.

The cases I reported with hemorrhage were those with spasm only; of those with complications many had hemorrhage into the bowel; all with carcinoma did, of course. At operation the surgeon has difficulty in telling what he has, even with the lesion in his hand. I have handed it to the pathologist and have had him confused. I used to think if you split the bowel open and saw an intact mucous membrane, you could say it was diverticulitis, but I have been fooled on that and have found carcinoma. Altogether it is quite a problem.

# RESECTION OF ABDOMINAL CARCINOMAS INVOLVING THE LIVER AND SPLEEN SECONDARILY*

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THE PURPOSE of this communication is to summarize the experiences gained in a limited series of patients who, at celiotomy presented carcinoma primary in an abdominal viscus with direct spread on to the liver or with metastases in the liver or spleen, and in whom the primary growths were excised *en masse* with the spread into the liver: when hepatic or splenic metastases were present the primary growths were excised as well as the metastases, at the same sitting.

The patients are divided into two groups: those only with direct spread on to the liver and those with discrete metastases in the liver or spleen. The histories are summarized as follows:

## DIRECT SPREAD ON TO THE LIVER

### CASE REPORTS

**Case 1.**—Nels. And. (261816): Male, age 68. Large palpable mass in the left upper quadrant. Roentgenograms revealed filling defect in lower stomach.

Celiotomy revealed a large carcinoma primary in lower stomach with direct spread on to the under surface of most of the left lobe of the liver. The lower three-fifths of the stomach bearing the neoplasm was resected *en masse* with the left lobe of the liver. Interrupted mattress sutures were inserted along the freshly cut-surface of liver to arrest hemorrhage. Pólya type posterior gastrojejunostomy (Fig. 1).

The patient is well and at work in a factory five years later.

**Case 2.**—Zarog. (263077): Female, age 58. Large carcinoma of hepatic flexure with extension on to undersurface and anterior edge of right lobe of liver; also, loop of ileum adherent to, and invaded by, carcinoma.

At operation, right hemicolectomy was performed including lower 30 cm. of ileum and corresponding mesenteries. The portion of liver on to which the carcinoma had extended and which measured 10 x 6 x 4 cm. was also resected *en masse* with the above. Interrupted mattress sutures were inserted along the freshly cut-surface of the liver (Fig. 2).

The patient, a diabetic, is living, well and normally active four years and ten months later.

**Case 3.**—Wei. (367851): Female, age 51.

Operation revealed a carcinoma of the pyloric portion of the stomach with direct spread on to the upper anterior aspects of the head of the pancreas and spread on to the liver in the region of the previous gallbladder bed. (Cholecystectomy had been previously performed.) Resection of the lower three-fifths of the stomach, areolar tissue of the porta hepatis, anterior superior portion of the head of the pancreas, first segment of duodenum (up to the junction with second portion) and nodes about the celiac axis with peritoneum over the anterior surface of the body of the pancreas and portion of liver to include old gallbladder bed, was carried out *en masse* (Fig. 3).

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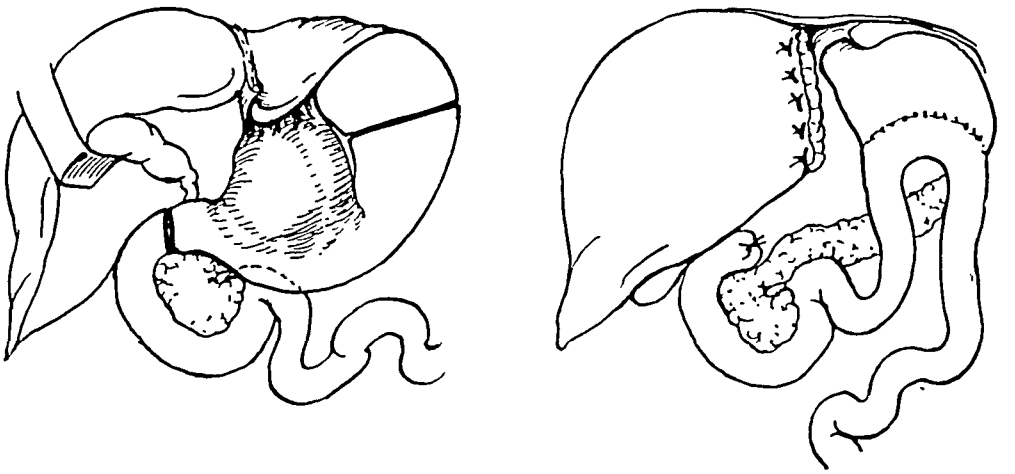


FIG. 1.—Diagram of radical gastrectomy for carcinoma invading under surface of left lobe of liver (Case 1). The latter was resected *en masse*, with major portion of the tumor. Patient alive and well, without evidence of recurrences five years later.

Convalescence was uneventful and the patient is living and well, 5 months after operation, without clinical evidence of recurrence.

**Case 4.**—Comin. (369037) : Male, age 40.

Two and one-half years previously received radical gastrectomy for carcinoma of stomach in another institution. At this admission complained of upper abdominal pain and vomiting after eating small quantities of food.

Celiotomy performed and extensive recurrences found about site of gastrojejunal anastomosis and in transverse mesocolon. There were extension on to under surface of left lobe liver and on to body of pancreas. Resection of all the remaining gastric stump with body and tail of pancreas, spleen, extensions on to left lobe of liver, transverse mesocolon and transverse colon and loop of jejunum employed for gastrojejunostomy. The continuity of the upper jejunum was reëstablished by end-to-end anastomosis. The terminal duodenum was anastomosed to the jejunum below its repair and the next long loop of the latter was brought up for esophageal anastomosis; entero-enterostomy was performed between new afferent and efferent jejunal loops.

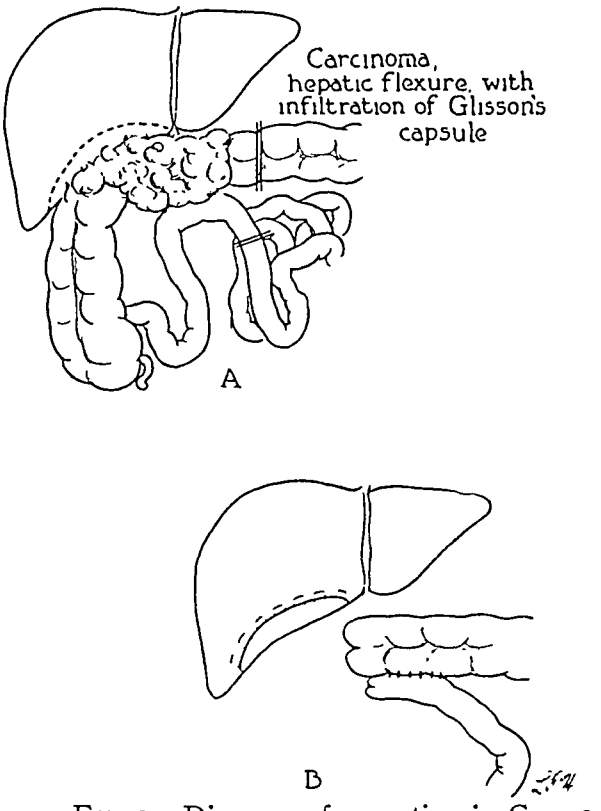



FIG. 2.—Diagram of operation in Case 2 (263077) showing right colectomy *partial hepatectomy* and partial enterectomy for large carcinoma of hepatic flexure that had spread onto right lobe of liver and secondarily invaded a loop of ileum. Patient alive and well, without evidence of recurrences four years and ten months later.

Five months after operation the patient is consuming a liberal diet and although still asthenic presents no clinical evidence of rapidly advancing carcinoma.

### DISCRETE METASTASES IN LIVER OR SPLEEN

**Case 5.**—La. (365356) : Male, age 36.

Two years previously received exteriorization resection of carcinoma of upper

descending colon, in another institution. At this admission presented recurrences in abdominal wall about the previous left paramedian incision. The largest recurrent nodule was suppurating.

The segment of left abdominal wall presenting recurrences was isolated by elliptical incisions extending from skin through peritoneum. It was then observed that the remaining descending colon was involved by the recurrence. There was extension of carcinoma into the upper left retroperitoneal space and there were four discrete metastases in the spleen. The entire region of recurrences was excised *en masse,* including spleen,

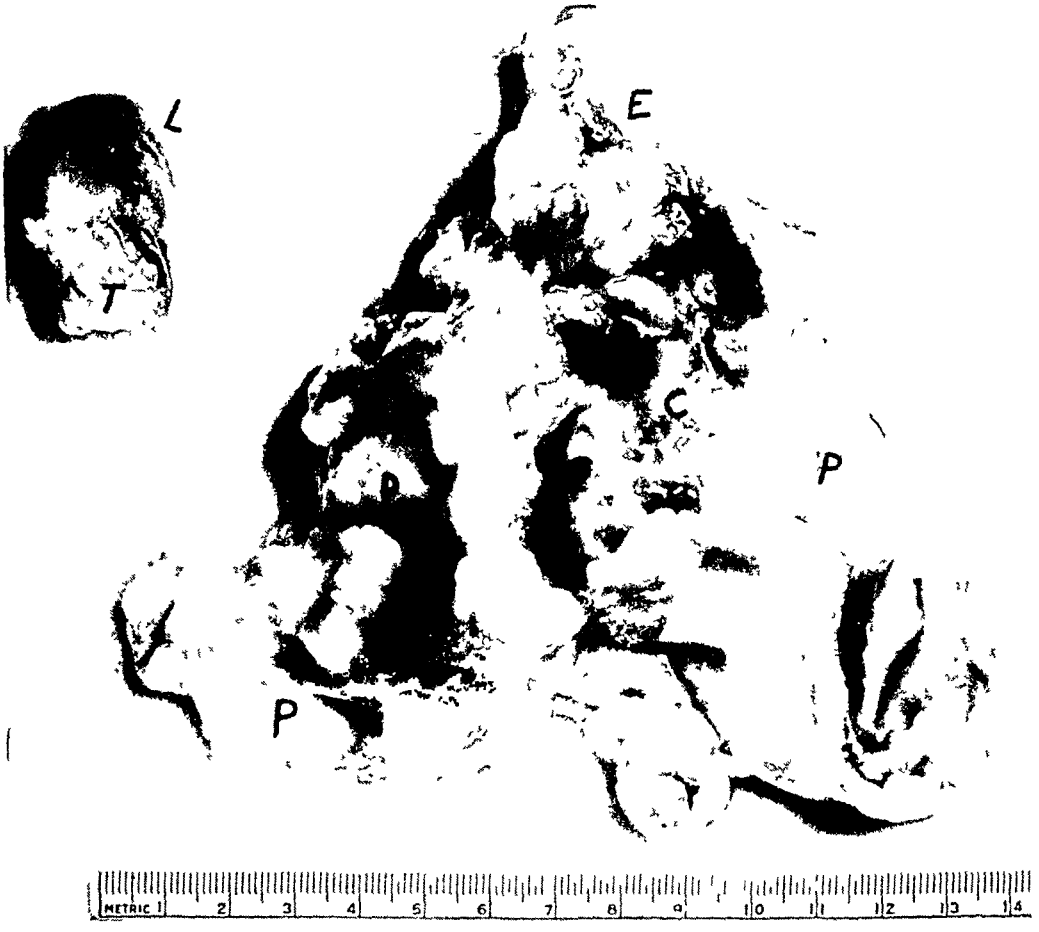



FIG. 3.—Case 3: Photograph of surgical specimens consisting of (P) pyloric portion of stomach with (C) carcinoma in its lower portion (D) first segment of duodenum; (P) anterior portion of head of pancreas; (E) areolar tissue from porta hepatis; (L) segment of liver from about old site of gallbladder with (T) direct spread of carcinoma. Patient living and clinically well five months after operation.

retroperitoneal tissues, left half of transverse colon, entire descending colon and segment of abdominal wall. Double-barrel colostomy, midtransverse colon to upper sigmoid. This was later closed (Fig. 4).

The patient is clinically well and back at work full-time, seven months after operation; he is a physician

**Case 6.**—Sol. (347132): Male, age 56.

Epigastric pain, three months duration; spherical mass palpated in epigastrium. At operation, the body and tail of the pancreas and spleen were resected for carcinoma arising in the midportion of the body, and measuring 10 x 7 x 3 cm. A metastatic mass, meas-

uring 3 cm. in diameter, situated in the right lobe of the liver near the anterior margin was resected with wedge-shaped segment of liver 6 x 6 x 5 cm. Uneventful recovery from operation. Died five months later of carcinomatosis.

**Case 7.**—Seeg. (349169) : Female, age 56.

Clinical history typical of acute cholelithiasis. At operation, multiple large metastases were found in liver about gallbladder. These apparently afforded clinical sign of rigidity in right upper quadrant and were the cause of pain. These large metastases were excised from the liver about the gallbladder and the latter, which was thickened and contained calculi, was also removed. The aggregate weight of the metastases was 594 Gm. The patient was relieved from pain but survived for only three months, dying of carcinomatosis. Histologic examination of the resected metastases revealed them to be composed of closely packed small anaplastic cells with minimal stroma. Necropsy was not obtained.

**Case 8.**—Dal. (142882) : Male, age 69.

Large upper abdominal mass. Roentgenograms revealed pyloric obstruction.

At operation, the liver extruded itself through the incision, with spontaneous fissuring of several of the metastases, resulting in severe hemorrhage. It was the liver enlarged by multiple metastatic masses that produced the upper abdominal mass. Excision of several of the metastases, each measuring 4 to 8 cm. in diameter, was carried out as a means of arresting the hemorrhage. To relieve the obstruction a pylorectomy, bearing the primary growth, was performed with Pólya gastrojejunostomy.

The patient succumbed 24 hours later, presumably of shock.

**Case 9.**—Gra. (361481) : Female, age 60.

Carcinoma palpable about 10 cm. above anal sphincter.

At operation, the lesion in the lower rectal colon was found to be about 4 cm. in length and to completely encircle the bowel. There was a tumor mass, 4 cm. in diameter, replacing the left ovary, a metastatic mass, 2 cm. in diameter, in the mesentery of the lower jejunum and a single metastatic mass, 2 cm. in diameter, in the right lobe of the liver. The latter was excised, and the mesenteric metastasis also resected. The left tube and ovary were resected. A redundant loop of sigmoid, 20 cm. in length, bearing the primary growth with corresponding mesentery was resected and low end-to-end anastomosis of the colon performed. A loop-colostomy was performed in the descending colon. The latter was closed six weeks after the previous operation. Satisfactory condition at home for four months; returned to hospital because of symptoms of low grade intestinal obstruction. Exploratory celiotomy again performed revealing generalized carcinomatosis; dense infiltration of entire pelvis by carcinoma. Loop-colostomy transverse colon. The patient died 5.5 months after the initial operation.

**Case 10.**—Pleu. (364479) : Male, age 62.

Diarrhea and blood in stools for seven months. No weight loss. At operation, a half fist-size carcinoma was found in the lower pelvic colon—half of it extended above the reflection of peritoneum from the pelvic floor. On the anterior surface of the right lobe of the liver a metastatic nodule, 1.5 cm. in diameter, was discovered. No other palpable metastases. The low midline incision was extended upward and the hepatic metastasis resected. A segment of pelvic colon, 18 cm. in length, bearing the primary growth together with corresponding mesentery was then resected and end-to-end anastomosis performed (Fig. 5). Since the lesion had produced appreciable obstruction and the upper segment of the anastomosed bowel was edematous a loop-colostomy was performed above the anastomosis. This was closed six weeks later. The patient is living, well and normally active as a machinist, seven months after operation.

DISCUSSION.—In the series of ten patients in whom resections of the primary growth and extensions or metastases to liver or spleen were excised




FIG. 4.—Case 5: Photograph of surgical specimen consisting of (S) spleen (bisected) showing three of four metastases from carcinoma primary in descending colon and removed two years previously. (W) Segment of left upper quadrant of abdominal wall and portion of underlying descending colon and omentum, (C) all of which was involved by recurrent carcinoma (a Mikulicz resection had been performed in this region two years previously.) (E) Extension of recurrent carcinoma into areolar tissues in retroperitoneal space of left upper portion of abdominal cavity. Patient living and well, with return to full-time occupation (no colostomy).

*en masse* at one sitting, one patient succumbed as a result of the operation, a surgical mortality of ten per cent. The results at this writing are summarized as follows:

Patients in whom there was direct spread on to the liver but no discrete metastases:

Case 1.—Living, well, and returned to full-time occupation.....5 years
Case 2.—Living, well, and returned to full-time occupation.....4 years, 10 mos.
Case 3.—Living, well, and returned to full-time occupation..... 6 months
Case 4.—Living and ambulatory .....4 months




FIG. 5.—Case 10: Surgical specimen consisting of lower sigmoid and upper rectal colon bearing (Ca) carcinoma. (T) Retroperitoneal tissues from concavity of sacrum. (M) Solitary metastasis from anterior surface of right lobe of liver. End-to-end anastomosis of upper sigmoid to lower pelvic colon. Patient clinically well seven months after operation, and returned to usual full-time activities.

Patients in whom there were discrete metastases in liver or spleen:

Case 5.—Living, well, and returned to usual occupation.....7 months
Case 6.—Died of carcinomatosis.....5 months
Case 7.—Died of carcinomatosis.....3 months
Case 8.—Died.....Died 2nd postop. day
Case 9.—Died of carcinomatosis.....5.5 months
Case 10.—Living and well, returned to usual occupation.....7 months

Direct spread of carcinoma onto the liver is obviously of more favorable prognosis than when discrete hepatic or splenic metastases have occurred. The satisfactory immediate results obtained in the patients described above, again, emphasize the fact that such spread is no contraindication to *en masse* excision.

Glisson's capsule serves as an effective barrier to the permeation of carcinoma cells into the liver parenchyma. When extension on to the hepatic surface occurs there appears to develop a considerable inflammatory thickening of the capsule which constitutes a dense barrier through which the neoplastic cells do not readily penetrate. Thus, apparent involvement of the liver by direct extension does not usually constitute the serious spread that might appear to have occurred. Indeed, when the surgical specimens are studied the neoplasms may be readily peeled away from the liver surface. Such a procedure at operation would not be justified, however, because some neoplastic cells might be left *in situ* adherent to the liver. It is preferable to excise through uninvolved liver parenchyma wide of adhesion of the neoplasm; this may be readily accomplished without undue hemorrhage.

At this point, mention may be made of the fact that on occasion in the presence of a primary neoplasm in an abdominal viscus the surgeon may encounter a small solitary nodule in the liver; the first impression is that this is a metastasis and the management of the primary growth is governed by such impressions. Frequently these nodules are not metastases but fibromas, scirrhous angiomas, or cysts. Thus, before final decision in regard to the nature of the procedure for the primary growth excision of the nodule and frozen-section biopsy is indicated.

Metastases to liver or spleen occur as the result of tumor emboli reaching these organs *via* the blood or lymphatic circulatory systems. The presence of such metastases, macroscopically visible, would suggest that other emboli of microscopic size have been seeded elsewhere in the liver and spleen as well as in other locations, although this might not have occurred since instances of solitary hepatic metastasis are not extremely rare at necropsy. The question, therefore, arises as to whether excision of the one, or few, visible metastases is justifiable. It may be said that if one, or few, metastases are visible there may be others deeply situated within the liver which would escape detection and, therefore, remain *in situ* and continue to develop. In favor of excision of visible metastases when they are solitary, or few, the following may be said: Some neoplasms develop slowly. In any given patient it is not possible to know how rapidly the neoplasm is developing nor how rapidly metastases are growing and being dessiminated. It is not a very unusual experience to observe patients survive for relatively long periods after one, or few, hepatic metastases have been observed, but left *in situ,* if the primary growth is resected for palliation. Therefore, excision of all macroscopic neoplastic tissue affords the full benefits of surgical therapy since there is no other treatment available. There is little experience to indicate whether or not such procedures would be worth while, and in the absence of final evidence that they are not, as would seem to be the implications from theoretic considerations, it would appear that there are no contraindications to an attempt to determine the answer on the basis of actual trial, inasmuch as the additional steps involved in excision of the metastases at the time the primary growth is

removed, do not constitute an added procedure of appreciable magnitude, in the properly selected patient (Fig. 6).

SUMMARY

In ten patients with primary malignant neoplasms in various abdominal viscera and with direct spread of one, or few, metastases into the liver or spleen the primary growths were excised *en masse*, with the direct extensions

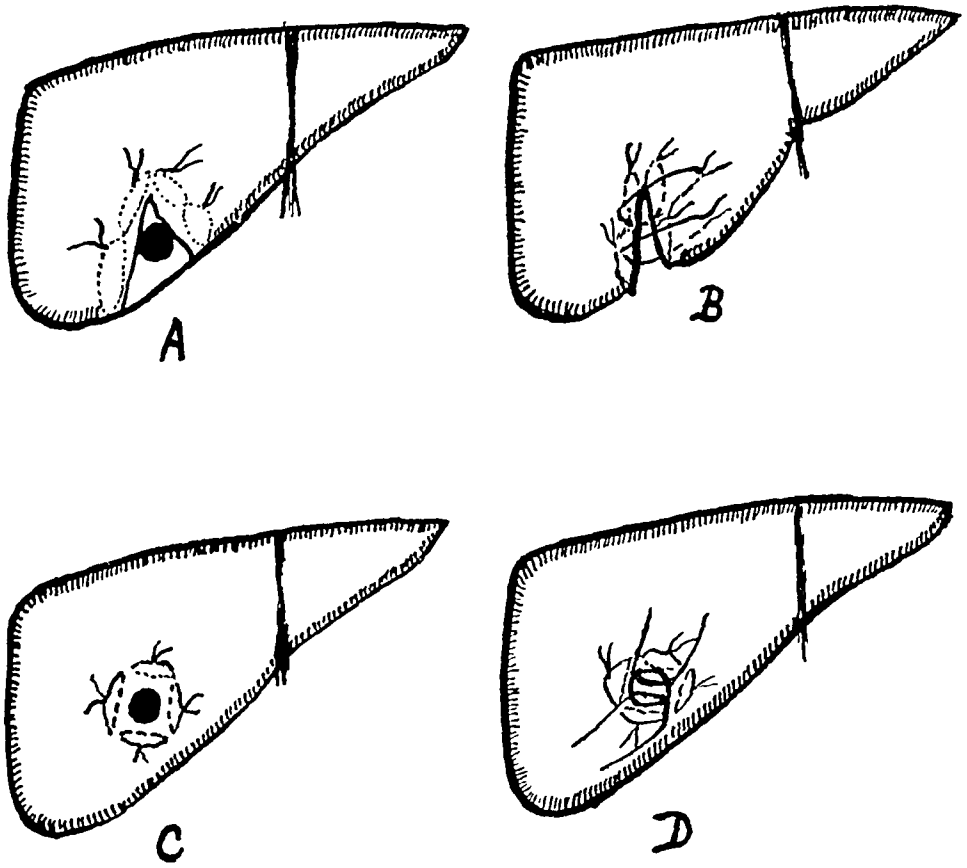



FIG. 6.—Diagrammatic illustration of methods for excision of metastatic masses in liver.

(A) Showing wedge-shape excision of segment of liver containing a metastasis. Mattress sutures inserted and tied before excision is carried out.

(B) Closure of defect in liver after excision.

(C) Metastasis away from margin of liver. Four mattress sutures inserted and tied before excision.

(D) Circular defect in liver collapsed by mattress sutures.

on the liver or with resection of the discrete metastases that were visible. The immediate surgical mortality was ten per cent (1 patient).

The best results were observed where the neoplasms had spread onto the liver and where discrete metastases were not present. It is suggested that increased palliation might have been achieved in some instances where metastases were excised but sufficient time has not elapsed for more definite confirmation of this impression.

In selected cases, such procedures may be carried out as they represent the maximal effort that surgery might afford, *i. e.*, the removal of all macroscopic evidence of neoplasm, when there is no other form of treatment now available.

DISCUSSION.—DR. DALLAS B. PHEMISTER, Chicago, Ill.: This is extreme surgery which Doctor Brunschwig has presented and it may easily be carried to too great extremes, as in case of excision of liver metastases. Nevertheless, it represents a real advance in both palliative and curative treatment of extensive malignant disease. Surgical principles must be utilized to the fullest in support of the circulation which is usually severely taxed. Both the theory of the cause of the embarrassed circulation and the methods of treating it are tested by these operations.

Because of the abundant sympathetic and vagal nerve supply to the upper abdomen it has been held that operations in this region are especially prone to cause circulatory failure as a result of nerve impulses arising from the trauma. However, it has been found that if, simultaneously, the great blood loss is compensated for by blood transfusion and the water loss by saline infusion, the operations are practically as well tolerated as are similarly managed operations in other parts of the body, while failure to replace blood and fluid loss results in circulatory failure. The reports of Stewart and Warner, Emerson and Ebert and Churchill reveal that extensive blood loss was the important cause of circulatory failure in war wounds of all parts of the body.

Since continuous spinal anesthesia is employed in most of these operations, the claim has been made that the anticipated shock is prevented by the blockage of nociceptive nerve impulses. However, some of them have been done under inhalation anesthesia with almost the same results. Also, the transthoracic resections performed for carcinoma in the upper abdomen are equally traumatizing and they show no predisposition to shock from nerve stimulation although all are done under inhalation anesthesia.

I believe that a study of these results will help to put an end to a chapter of imaginative writing on the great importance of nerve impulses as a cause of circulatory failure from operations in this and other fields.

DR. ALEXANDER BRUNSCHWIG, Chicago, Ill. (closing): An efficient blood bank must be available if massive resections for advanced cancer are to be undertaken. I need not go into the value of whole blood in the treatment of shock.

The question of surgery in advanced carcinoma, especially of the types presented, brings up the whole problem of immunity to cancer. If one injects an animal with certain types of transplantable tumors, removes the growth after a period and then reinoculates it, the second implant will not grow, or grows much more slowly. When a primary growth is removed the human patient may do very well for a number of years and then suddenly succumbs to an explosive development of metastases. I had one patient who had a melanoma of the eye resected 25 years previously. On admission, the complaints were of only six months' duration; prior to that time he was very active in every way. At necropsy, his entire body was found to be riddled with melanoma metastases. Some factor apparently held the widespread disseminated tumor cells in check for a number of years. An important point to consider in connection with patients of the type presented here is whether, after removal of all large macroscopic evidences of tumor, there may not be a degree of immunity sufficient to restrain growth of microscopic masses of neoplastic cells.

# DEFINITIVE SURGERY OF THE LARGE INTESTINE FOLLOWING WAR WOUNDS

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AT THE TIME of World War I modern colon surgery had reached only its first great milestone. The contributions of Heinecke, Block,[1] Paul,[2] and Mikulicz,[3] resulting in the development of the Paul-Mikulicz technic had allowed surgeons of that day to attack the diseases of the colon with some chance of success. However, surgeons prepared only with a surgical technic and without modern chemotherapeutics and antibiotics were unable adequately to cope with the casualties sustaining wounds of the colon or rectum in that war. Wounds of the colon constituted 22% and wounds of the rectum 2.4% of all the intra-abdominal visceral injuries in the United States Army in World War I, and carried a mortality rate of 59.6% and 45.19%, respectively.[4]

Complete statistics are not yet available for World War II but it is safe to state that one of the most impressive achievements of the military surgeon will be in the lowered mortality rates for intra-abdominal wounds in general, and particularly wounds of the colon and rectum. It is reasonable to expect that when the final figures are published the mortality rates for these three types of wounds may approach one-third the rate in World War I.

The many factors contributing to these favorable results have received ample publicity and description. The use of sulfonamides, penicillin, plasma and blood transfusions, rapid evacuation and prompt treatment at forward medical installations have all received due credit. However, one of the most important factors in reducing the death toll of colon and rectal wounds has not received its due recognition, namely, the routine establishment of a temporary colostomy in all wounds of the colon, rectum, and certain perineal and buttocks wounds.

Shortly after the close of the North African campaign the Surgeon-General[5] had the wisdom to issue a directive that all wounds involving the large bowel should be exteriorized, if possible, as a temporary colostomy, otherwise sutured and a proximal colostomy established, and in certain perineal and buttocks wounds it was directed that a colostomy be performed as adjuvant to wound healing and secondary suture. The strict adherence to this directive has mate-

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rially contributed to the reduction in both the mortality and morbidity of wounds of this nature. This technic coupled with chemotherapy and modern supportive measures saved the lives of many grievously wounded soldiers. However, this materially increased the cases requiring definitive surgery of the colon and rectum. Many of these cases required multiple operations before they could be restored to normal life. Although many colostomies were closed overseas, a large number of these cases, particularly those with more extensive injuries were returned to General Hospitals in the United States for definitive surgery.

The material on which this paper is mainly based consists of 96 consecutive cases requiring large bowel surgery admitted to the Septic Surgery Section of Rhoads General Hospital, Utica, New York (Table I).

TABLE I

TYPES OF LESIONS ENCOUNTERED IN 96 CASES OF WOUNDS OF THE LARGE INTESTINE REQUIRING DELAYED REPARATIVE SURGERY

| Type of Lesion | No. of Cases |
|---|---|
| Temporary colostomy: | |
| Simple exteriorization | 35 |
| Proximal defunctioning | 46 |
| Fecal fistulae | |
| Traumatic colostomy | 5 |
| Surgical (cecostomies for damage to cecum or terminal ileum) | 7 |
| Following extraperitoneal closure of colostomy elsewhere | 7 |
| Trans-sacral rectal perforation | 9 |
| Ileostomy and Ileocecostomy | 6 |
| Laceration of anal sphincter | 7 |
| Rectovesicocutaneous fistula | 5 |
| Complete colonic obstruction | 2 |

## THE PROBLEMS OF REPARATIVE SURGERY OF THE LARGE BOWEL

The patients included in this series form a representative group of all casualties admitted for large bowel surgery. They varied in age from 18 to 35 years. Prior to sustaining their wounds they had all been classified as fit for full field service.

The average length of hospitalization overseas prior to admission to Rhoads General Hospital was about ten weeks. However, the Medical Department facilities for evacuation of the wounded functioned so efficiently that 5% of these cases were admitted to our service within three weeks of the date they were wounded.

In consequence of this wide variation of the time factor following the date of injury and admission to this hospital, there was a correspondingly wide variation in the general physical status of these patients.

Only ten cases, or 10.6%, showed marked evidence of malnutrition. Only three cases, or 3.2%, showed an hypoproteinemia on admission. However, all cases admitted showed an appreciable weight loss. This varied from ten to 80 pounds. Three of the patients had lost 50% of their body weight by the time of their admission to Rhoads General Hospital. One of the important prob-

lems, therefore, in the management of these cases was that of determining the optimum time to institute reparative surgery. The solution varied with each individual case and depended greatly upon the number, extent, and urgency of the procedures contemplated. As a general rule, however, major surgery was withheld until all clinical and laboratory evidence of malnutrition had disappeared. Whenever possible, the patient was carefully managed until he regained all but ten pounds of his former body weight.

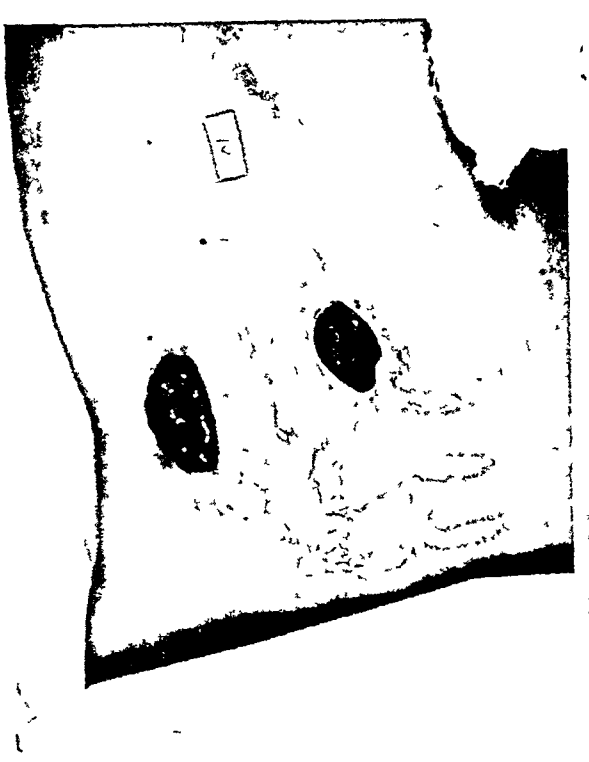


FIG. 1

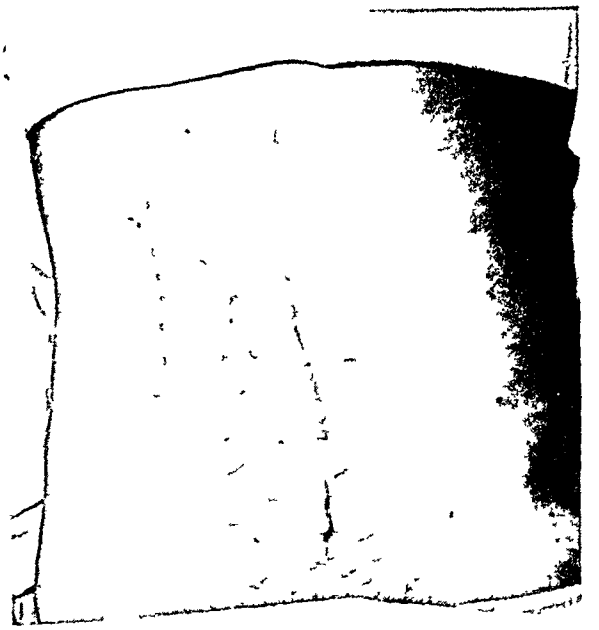


FIG. 2

FIG. 1.—Case 50: Showing two antimesenteric colostomies of transverse colon.
FIG. 2.—Case 50: Same patient as in Fig. 1, following consecutive closure of both colostomies.

Any attempt to convey by verbal description the composite picture presented by these patients as a group upon admission, to those who did not deal with casualties, is impossible. Even the attempt to classify the problems encountered is unsatisfactory; however, two outstanding features characterized this group as a whole. The wounds were extensive. There was a multiplicity of lesions. Because of these factors a case frequently fell into two or three descriptive categories. As a result, no single category contains a large number of cases. Therefore, for the purposes of discussion, we have chosen to describe certain problems only which were matters of concern and which presented interesting surgical conditions.

By far, the most important problem of reparative large bowel surgery was the closure of colostomy (Table I). From the standpoint of the number of cases involved, the future comfort and welfare of the patient, and the application of our work to civilian surgery, the problem of the most satisfactory method of closing a temporary colostomy occupied the place of chief impor-

tance. A total of 86 colostomies are reported in this series. We will deal at length hereafter with the method of closure and results obtained.

*Multiple or Secondary Colostomies:* Closely associated with the problem of colostomy closure was the management of those cases who had two colostomies, or an ileostomy and a colostomy (Figs. 1 and 2).

There were six such cases in this series. Two secondary colostomies were established following the admission of the patients to Rhoads Hospital. A secondary colostomy was performed when the initial colostomy failed to function properly, or when complete diversion of the fecal stream was paramount and not achieved by the former colostomy, or proximal to traumatic colostomies with extensive damage to the colon and abdominal wall. In this latter type of injury it was felt that the reconstructive surgery would be of such an extensive nature that defunctionalization of the colon containing the traumatic colostomy was essential. Case 1 illustrates this type of management. When definite indications for secondary colostomy are present, it is the opinion of the authors that it should be performed unhesitatingly. The advantages which will be obtained outweigh the disadvantages of additional surgery; the total morbidity will be decreased and superior end-results obtained.

Case No. 1.—This 21-year-old soldier was admitted to Rhoads General Hospital on November 15, 1943. History on admission revealed he sustained a machine gun bullet wound of the abdomen on September 16, 1943. The bullet penetrated the left lower quadrant, where it was shattered. Some of the fragments perforated the sigmoid colon and others fractured the left ilium. Patient lay on field for six days after he was wounded before he was found and taken to a clearing station. Celiotomy revealed that he had a huge intra-abdominal abscess which, when evacuated, resulted in the development of a traumatic colostomy of sigmoid colon.

Examination on admission revealed malnutrition. In the left lower quadrant, just above the middle of the inguinal ligament, was a granulating, infected wound extruding fecal matter. The sides and floor of this wound consisted of sigmoid colon. Just below this wound was a subcutaneous abscess which crossed the entire lower abdominal wall. There was also limitation of flexion, internal and external rotation of the left hip. Roentgenologic examination showed a comminuted fracture of the left ilium involving superior lip of acetabulum, with osteomyelitis.

Shortly after admission, patient developed malaria, which responded promptly to atabrine therapy. Because of his weakened condition and underweight, he was placed on high protein, high caloric and high vitamin diet.

On January 27, 1944, under sodium pentothal anesthesia, the lower abdominal wall abscess was incised, drained and allowed to granulate from the base. Healing progressed satisfactorily and by February 8, 1944, wound was completely healed. The traumatic colostomy decreased in size, but it was apparent it would not close spontaneously. Accordingly, on February 18, 1944, an excision of scar at lower border of wound was performed, revealing a sinus tract beneath the lateral edge of the lower third of the wound, which communicated with site of fracture of the acetabulum. The problem of closure was now considered. Because of the large defect in the abdominal wall surrounding this wound, it was felt that closure of the traumatic colostomy was inadvisable. It was also felt that the osteomyelitis of the acetabulum could not be cleared up until the fecal stream discharging into the wound could be eliminated. Therefore, on March 27, 1944, under spinal anesthesia, a secondary double-barrelled, transverse colostomy was performed, thus diverting the fecal stream from the descending and sigmoid colon.

Sequestrectomy of the left ilium through a clean incision on the left thigh over the capsule of the hip joint was performed on April 25, 1944 under spinal anesthesia. The wound was packed, and healed satisfactorily. However, the sinus tract extending medially into the colon persisted. It was then decided that the traumatic colostomy was keeping the sinus tract open and the osteomyelitis active, despite the fact that no fecal matter was present. Accordingly, on June 7, 1944, under general anesthesia, a closure of the sigmoid, traumatic colostomy was performed. The abdominal wall closure, by necessity, was incomplete, resulting in a defect 7 x 6 cm. extending down to the peritoneum. The wound healed rapidly by granulation from the base, but permitted the development of a small ventral hernia. The sinus tract closed shortly thereafter, and the osteomyelitic process subsided completely.

On July 11, 1944, under spinal anesthesia, a closure of the transverse colostomy was performed. His convalescence was satisfactory, and his bowel function was entirely normal.

Repair of ventral hernia was postponed in view of the extensive surgery this patient had been subjected to in the past six months.

*Fecal Fistula:* The repair of persistent large bowel fistulae is a common difficult problem following war wounds. A total of 14 persistent fecal fistulae were included in this series, as shown in Table I. Seven of these cases were the result of unsuccessful attempts at closure of colostomy overseas by the extraperitoneal method. The others were the result of surgical and traumatic cecostomies, traumatic colostomies and rectal perforations, as illustrated by Cases Nos. 1 and 5. These presented most difficult problems in surgical judgment and management. The rationale in the management of all fecal fistulae was the same as for colostomy closure, as illustrated in Case No. 5.

Case No. 5.—This officer was wounded on July 5, 1944, by a rifle bullet, point of entrance above right iliac crest, point of exit left flank. Celiotomy performed shortly after injury revealed multiple perforations of jejunum, ileum, severe laceration of sigmoid colon; and laceration of the left ureter.

At operation, a small portion of severely injured small bowel was resected and end-to-end anastomosis accomplished. The multiple perforations of small bowel and the laceration of the sigmoid colon were sutured, and a loop of transverse colon was brought out through the upper end of celiotomy incision to establish a colostomy. However, when the wound was redressed within the next 48 hours, the transverse colon had retracted into abdominal cavity, and thus a temporary colostomy to divert fecal stream was not accomplished. This failure to sidetrack the fecal stream resulted in the breakdown of the repair of the sigmoid colon with the formation of a fecal fistula through the wound of exit.

Through this wound a urinary fistula also drained. A ureteral catheter was placed into the left ureter for treatment of the urinary fistula. Following this the urinary fistula healed, but the fecal fistula persisted.

Admitted to Rhoads General Hospital in November, 1944. On admission patient's general condition was fair. He was having a few bowel movements by rectum each week, but the major portion of the feces passed through the fistula in the left flank.

The physical examination was essentially negative except for severe excoriation at site of fistula and a small incisional hernia at the upper angle of the celiotomy scar.

Laboratory findings on admission revealed a severe urinary infection. Colon organisms were cultured. This responded promptly to oral sulfadiazine therapy. Intravenous and retrograde pyelography revealed no evidence of the previous ureteral fistula.

A cecostomy was performed on December 4, 1944, preparatory to repair of patient's sigmoid colon.

Ten days later, the abdomen was explored and the sigmoid colon found densely adherent to the left iliac fossa. This was partially freed, the fecal fistula was exposed, the margins of the fistula were excised and a transverse closure of the bowel accomplished.

Seventeen days later the cecostomy tube was removed and the following day the patient had a normal bowel movement. Within five days the patient's wounds were completely healed; however, he had persistent abdominal cramp-like pain and diarrhea.

Barium enema, January 23, 1945, showed a marked narrowing of sigmoid colon, just below the site of the fecal fistula. This had not been observed at time of operation.

The hernia noted at the wound of exit in the left flank was repaired on July 16, 1945, and, also, at that time the entire sigmoid colon was freed from the left iliac gutter.

Barium enema following this procedure showed an increase in the caliber of the sigmoid colon. The patient's symptoms of diarrhea and cramp-like abdominal pain were markedly alleviated. He was able to eat all types of food, except those containing large amounts of roughage, milk and milk products, and regained his normal weight.

*Trans-sacral Perforation of the Rectum:* Nine cases had penetrating wounds of the rectum produced by a missile perforating the sacrum or sacrum and coccyx. Several of these were among the most trying cases with which we had to deal. Two of these cases healed spontaneously under proper management. In both cases, a proximal colostomy completely diverted the fecal stream. In one of these, a secondary colostomy was performed following admission because the initial colostomy failed to accomplish this. No further treatment was necessary. The second case had a defunctioning proximal colostomy on admission, but the fistula persisted. Perforated capsules of sulfaguanidine were inserted into the distal loop, using one gram three times a day. The distal loop was irrigated daily with acriflavine, one to ten-thousand, using 500 cc. three times a day. Externally, wet dressings of penicillin were applied. On this regimen, the fistula closed two weeks after admission. These two cases were the exceptions. The majority did not close spontaneously. There were several reasons for this. Most of these cases developed an osteomyelitis of the sacrum or coccyx. Closure of the fistula occurred only after the removal of the infected bone. A second factor in these trans-sacral fistulae was the marked tendency of the rectal mucosa to eversion and proliferation, in front of the sacrum and along the sinus tract. In one of our cases, fully one-third of the circumference of the rectal wall was destroyed, leaving a large defect. Three operations were necessary to repair this defect, following which his colostomy was closed (Fig. 3).

The successful surgical closure of trans-sacral rectal defects requires three steps that are important. The first is excision of the coccyx and as much of the sacrum as is safely permissible and necessary to allow adequate exposure. Secondly, it is important to achieve as much mobilization of the rectum as possible, both laterally and in front of the sacrum. Finally, and most important of all, is the interposition of some fat or muscle tissue between the portion of rectum containing the transverse closure and the sacrum before closing the skin. Complete hemostasis should be obtained and the wound closed tightly without drainage.

*Rectovesicocutaneous Fistulae:* One of the most complicated types of wounds encountered were those in which complete perforation of the lower pelvis produced a rectovesicocutaneous fistula (Fig. 4).

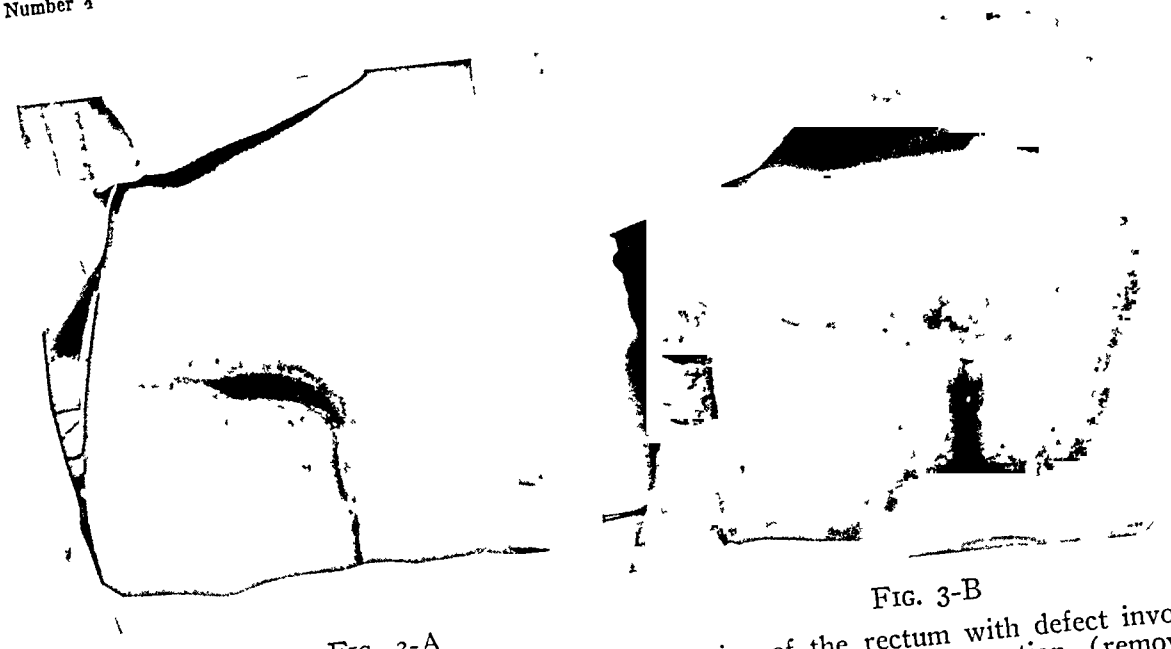


FIG 3-A

FIG. 3-B

FIG. 3-A.—Case 46: A trans-sacral perforation of the rectum with defect involving one-third circumference of posterior rectal wall Taken after first operation, (removal of sacral sequestra).

FIG. 3-B.—Case 46· Postoperative view of same patient.



FIG. 4.—Case 15: Rectovesicocutaneous fistula showing suprapubic cystotomy and proximal colostomy.

However, if properly managed, these wounds healed surprisingly well. Cardinal points in their management were a completely defunctioning proximal colostomy and a satisfactory suprapubic cystotomy in conjunction with an indwelling urethral catheter. If these two operative procedures were carried out promptly and satisfactorily, the communication between the rectum and bladder usually healed spontaneously, as did the communication between the bladder and abdominal wall.

All vesicocutaneous fistulae also healed spontaneously except in one case where there was marked loss of substance of the anterior abdominal wall. However, these patients were subject to many complications. The most disturbing complication was an extravasation or spilling of urine in the neighboring wounds, with resulting sinuses and their sequelae. A moderately severe cystitis occurred in most cases and resumption of normal urination was frequently accompanied by a most annoying epididymitis.

*Marked Destruction of Large Intestine with Loss of Substance:* Some cases showed marked damage of the bowel with a resulting loss of considerable substance. This type of injury predominantly occurred in the cecum; however, Case No. 24, which will be described later (Fig. 7), showed marked loss of the descending colon and Case No. 7, partial loss of the sigmoid colon.

Marked damage to the cecum frequently necessitated the exteriorization of the cecum and terminal ileum as an ileocecostomy. (Case No. 57.) A careful examination of the exteriorized bowel usually showed extensive damage at the ileocecal junction. Often, two, three, or more large rents were present in this area. In one case, the ileocecal valve was completely destroyed. In these cases an attempt to restore the normal anatomic relationships was either impossible or too uncertain to be justified by the expected end-result. Therefore, a proximal ileotransverse enterocolostomy, using a side-to-side anastomosis with resection of the cecum and ascending colon, was the procedure of choice. These cases all showed an excellent end-result. The repair of wounds of the large bowel with loss of substance was greatly facilitated or made feasible by the use of the open anastomosis technic, to be described later.

Case No. 7.—This 33-year-old soldier was injured October 10, 1944, by rifle bullet, point of entrance left buttock, point of exit, suprapubic region. Celiotomy shortly after injury revealed perforations of the liver, terminal ileum, sigmoid colon and bladder. The perforated sigmoid colon was exteriorized because of marked loss of substance of the antimesenteric wall of the bowel; and a double-barrelled ileostomy and suprapubic cystotomy were performed. Patient was treated symptomatically, including plasma and whole blood, and his postoperative course was uneventful.

Admitted to Rhoads General Hospital January 24, 1945; his general condition was reasonably good, but somewhat emaciated. Chief complaint was severe excoriation around his ileostomy.

Examination revealed yellowish discoloration of the skin due to atabrine suppressive therapy. The abdomen was scaphoid. The right lower quadrant presented a well-functioning double-barrelled ileostomy; around the stomata the skin was markedly excoriated and tender. In the left lower quadrant was a simple antimesenteric colostomy. In the midline was a partially healed cystotomy, from which a small amount of urine escaped. Other injuries and physical findings were noted but are irrelevant.

The excoriation of the abdominal wall was promptly controlled with aluminum paste, and the patient's general condition and nutrition showed rapid improvement. All necessary laboratory work (including barium enema, G. I. series, blood studies and total serum proteins) was done.

Patient was prepared in routine manner for colostomy closure, which was accomplished on March 21, 1945.

The operation presented a technical difficulty in that a loop of the ileum was intimately fused to the site of the colostomy necessitating resection of a segment 6 cm. long. The continuity of ileum was reestablished by end-to-end anastomosis. The colostomy was closed by routine technic as described for the lateral type. The postoperative treatment was routine, and his course uneventful.

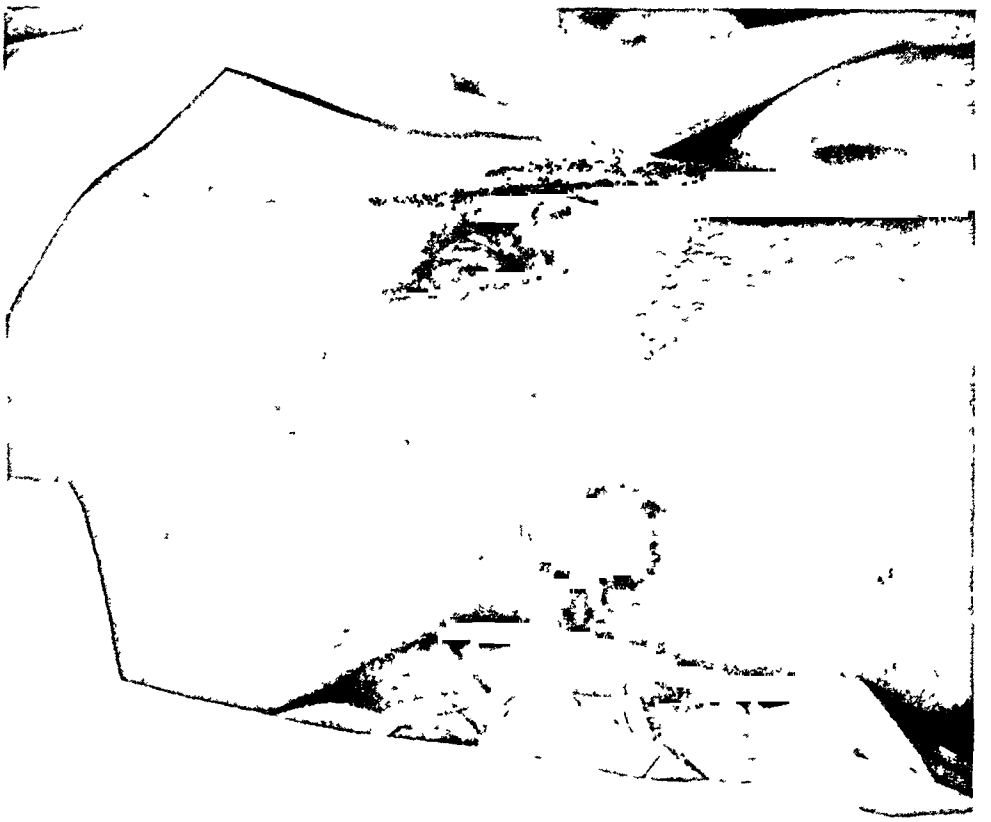


FIG. 5.—Case 57: Ileocecostomy performed for marked damage to ileocecal valve and terminal ileum. Wound of entrance also shown.

On April 27, 1945, the ileostomy was closed by end-to-end anastomosis. The preoperative and postoperative care were routine. His postoperative course was uneventful.

Postoperative G. I. series and barium enema showed satisfactory anastomosis, both in sigmoid colon and terminal ileum.

Upon discharge, his physical and mental status were good. All the wounds were healed; he was having regular, normal, daily bowel movements and was completely asymptomatic.

Case No. 57.—This 21-year-old male was injured by machine gun bullet September 26, 1944, (France). Bullet entered right lumbar area, and made its exit through anterior abdominal wall. He was evacuated to a Field Hospital, where an exploratory celiotomy revealed a traumatized lower edge of right lobe of liver, multiple perforations of the ileum and perforated cecum. A resection of a portion of the traumatized ileum and end-to-end

anastomosis were accomplished. The extreme portion of the terminal ileum and the cecum were so lacerated that they were exteriorized as an ileocecostomy (Fig. 5).

On admission to Rhoads General Hospital chief complaint was excoriation of abdominal wall about the ileocecostomy, which was promptly controlled by aluminum paste.

Examination revealed an ileocecostomy in the right lower quadrant. There were three openings in the terminal ileum and exteriorized portion of the cecum.

Laboratory studies other than roentgenograms were negative. Barium enema showed normal colon. Instillation of barium into terminal ileum showed a constant constricting defect 15 cm. from the ileostomy.

At operation, January 29, 1945, the cecum and terminal ileum were found to be so badly damaged that it was impossible to reëstablish the anatomic structures of the ileocecal region. Accordingly, an ileotransverse colostomy was performed, anastomosing the terminal ileum proximal to the strictured portion, described in the roentgenogram (Fig. 5), to the proximal one-third of transverse colon. The ileum distal to the anastomosis was transsected. The ileocecostomy was left in place. Patient made an uneventful recovery. Barium enema four weeks later showed a satisfactory anastomosis. On March 5, 1945, the terminal ileum, the cecum and ascending colon were resected. Abdomen was closed without drainage. Postoperative course was satisfactory. Recheck barium enema again showed satisfactory anastomosis.

Upon discharge, bowel function was normal and patient completely asymptomatic.

*Foreign Bodies:* For the most part, retained intra-abdominal or pelvic foreign bodies found in conjunction with large bowel wounds were asymptomatic. No attempt was made to remove these. The removal became necessary when they were responsible for persistent sinuses leading to the colon, or pericecal, colonic, or rectal abscess or phlegmon. Four cases of this type are included in this series. The removal of a foreign body usually entailed a very difficult surgical procedure. In one case, a large shell fragment lying in the pelvis, between the rectum and sacrum, produced a perirectal cellulitis, causing marked pelvic pain.

Barium enema revealed a rigidly fixed rectum displaced to the right. Overseas, an unsuccessful attempt had been made to extract the fragment by a posterior retroperitoneal approach. On admission to Rhoads Hospital the foreign body was still present. After preoperative preparation, including sulfadiazine, the foreign body was removed by an anterior, transperitoneal route. The patient made an uneventful recovery, following which his colostomy was closed. Case No. 16 illustrates even more vividly the extreme difficulty caused by infections resulting from foreign bodies.

Case No. 16.—This 32-year-old soldier was injured in France July 6, 1944, by a hand grenade accidentally exploding in his rear pocket. He sustained multiple severe wounds of the right and left buttocks, right and left thighs and legs, compound fracture of the left radius and a penetrating wound of the rectum. The following day a sigmoid colostomy was established. However, this colostomy retracted, thus, failing to divert the fecal stream, resulting in the formation of five fecal sinuses in the left buttock. Therefore, a Devine colostomy of the transverse colon was performed on July 27, 1944, following which the patient developed a paralytic ileus which was satisfactorily controlled with Miller-Abbott tube suction. Patient was evacuated by air to the United States and admitted to Rhoads General Hospital.

Upon admission, examination revealed the patient to be pale, exhausted and somewhat emaciated. His general condition was good and the colostomy was functioning satisfactorily.

Roentgenograms taken shortly after admission showed eight metallic foreign bodies

in the pelvic region. Barium enema revealed the barium to flow from the lower rectum about 4.5 inches from the anus to the right around a large foreign body and reënter the rectum proximally, forming a fistulous loop. Therefore, colostomy closure was postponed. Serial barium and skiodan enemas, and sigmoidoscopic studies were performed which showed the fistulous tract to be decreasing in size, and spontaneous closure seemed likely. However, after several months of observation it was still patent; therefore, January 15, 1945, an exploratory celiotomy was performed in an attempt to locate and remove the perirectal foreign body. A careful and thorough search failed, however, to locate it. His postoperative course was uneventful (Fig. 6).



FIG. 6.—Retained metallic foreign body. Sinus tract leads from upper rectum to f.b. and back into lower rectum.

Barium enema five weeks after this operation, for the first time, showed no evidence of a sinus tract leading from the rectum to the foreign body. Apparently, this had closed spontaneously. Repeat barium and skiodan enemas and sigmoidoscopic studies failed to reveal the slightest evidence of the former patent fistulous tract. Therefore, after routine preparation, on May 2, 1945, closure of the Devine-type colostomy was accomplished. His postoperative course was essentially uneventful until the 26th postoperative day. At that time, he presented definite evidence of a deep-seated cellulitis in the left buttock. Five days later, an incision and drainage of an extensive left perirectal abscess was performed. A sinus tract at the bottom of the abscess cavity was probed and found to extend toward the right. Definite origin of this abscess could not be established.

Following this episode, he had recurrent deep-seated perirectal abscesses requiring incision and drainage. On June 29, 1945, a foreign body was removed from the left buttock, with no apparent benefit. There was an associated persistent draining sinus tract in the left buttock. This sinus tract was identified roentgenologically with the aid of lipiodol, skiodan and probe, and found to communicate with the initial fistulous loop and the foreign body

on the right side of the rectum. It was very apparent at this time that the fistulous tract had probably reopened and that the draining sinus and recurrent perirectal abscesses could be cured only by removal of the underlying etiology, namely, the foreign body. Therefore, on November 21, 1945, an exhaustive localization was done. Cystography was performed to study the relationship of the full bladder to the rectum and lipiodol instilled into the sinus tract to study their relationship to the foreign body. Vertical and transverse wires were also used, in addition to five metal numerals arranged in a square formation, with the fifth in the center. Finally, when the exact location and depth of the foreign body was known, a long skin needle corresponding to the depth of the foreign body, threaded with silk, was passed down to the foreign body so that the eye portion of the needle was just beneath the skin. Roentgenograms showed the point of the needle to just reach the upper edge of the foreign body in the right pelvis. In view of the absolute localization and the danger that the needle might have passed through some important structures, the patient was immediately taken to the operating room with needle in place. This time, an incision was made through the right buttock. This was carried down, using the needle as a guide, the point of which was known to be directly on the foreign body. The foreign body was located on the anterior, left, lateral aspect, at the level of the lower and middle-third of the rectum, and removed. The postoperative course was entirely uneventful. The constant, tender, painful induration of the left buttock promptly subsided and the persistent draining sinus closed completely.

*Laceration of the Anal Sphincter:* Extensive laceration of the anal sphincter was encountered in seven cases. These required multiple operations to repair. The value of the completely defunctioning colostomy was readily apparent in these cases. Because of the absence of fecal contamination these plastic repairs healed almost as well as clean wounds. Despite extensive loss of sphincter substance it was possible to restore satisfactory function in all cases. The technic which we employed can briefly be described: A semicircular incision paralleling the anal orifice about 3 cm. from the mucocutaneous junction was used. The sphincter was approached, scar tissue excised and the severed ends mobilized, and the defect closed with mattress and interrupted sutures of chromicized catgut. If the defect could not be closed it was reduced as much as possible by anchoring the free ends, and the wound was closed. After several weeks of dilatation and sphincter control exercises a second operation was performed in a similar manner. It was then possible to unite the severed ends. When more than one interruption of the sphincter was present, one trans-section was repaired at a time. The importance of sphincter control exercises and rigid adherence to daily dilatation cannot be too strongly stressed.

In the surgical management of cases with colostomy and anal sphincter injury or repair, it is of essential importance to test the sphincter action and control before the colostomy is closed. This may be simply accomplished by the instillation of commercial starch in water into the distal loop or rectum, or both, and observing the sphincter control and power of interruption.

It is disturbing, to say the least, to both surgeon and patient to recognize an inadequate sphincter following colostomy closure. It is an inexcusable mistake which can and should be avoided.

*Marked Loss of Substance of the Abdominal Wall:* This serious complication was encountered in four cases. In two cases, following the closure

of colostomy, it was impossible to repair the loss of abdominal musculature, and only the peritoneum could be closed. Later, plastic procedures were carried out to repair the abdominal wall defects. (See Case No. 24 below.) One case was sent to a Plastic Center for repair of marked loss of the lower abdominal wall which prevented closure of vesicocutaneous fistula. The fourth case had a severe vesico-ileal fistula which communicated with an abscess extending beneath Poupart's ligament to the right hip joint. The anterior two-thirds of the bladder were completely exposed. An ileotransverse enterocolostomy was performed successfully, side-tracking the vesico-ileal fistula.

*Associated Intestinal Obstruction:* In an earlier paper two of the authors[6] have presented the problem of intestinal obstruction as a late complication of war wounds. This was a complication in nine cases included in this series, all of which occurred before colostomy closure at Rhoads General Hospital. As shown in Table II, five cases showed incomplete small bowel obstruction. These were treated by duodenal suction-decompression, with recovery. In all cases, partial obstruction was proven at subsequent operation; performed either for closure of a colostomy, or for repeated episodes of partial obstruction. In three of these cases, the small intestine was found intimately adherent to the colon and anterior abdominal wall at the site of exteriorization of the colostomy. Two cases had complete small bowel obstruction. One of these cases (Case No. 24) obstructed on two occasions before an extensive traumatic colostomy and secondary colostomy could be closed.

Case No. 24.—This 30-year-old soldier was wounded in Germany, March 12, 1945, by a high explosive shell fragment. He sustained a severe wound of the left flank, with marked loss of substance of the lateral abdominal wall. The wound was débrided shortly after injury and it was the opinion of the operator that the peritoneal cavity had not been entered. His postoperative course was fulminating, and, on the 8th postoperative day, there occurred the spontaneous rupture of a fecal abscess through the wound in the flank. Examination revealed marked destruction of the proximal descending colon. The following day, a proximal transverse colostomy was performed and the patient promptly improved (Fig. 7).

Twenty-eight days after injury, this soldier was evacuated by air to the United States and admitted to Rhoads General Hospital, April 9, 1945. Upon admission, he appeared toxic and exhausted, and complained of nausea and moderate cramp-like abdominal pain, His colostomy had not functioned for 24 hours. Following the instillation of oil into the proximal loop of his colostomy he had a copious evacuation and all symptoms disappeared.

At 1 P.M. on the following day he complained of cramp-like abdominal pain of increasing severity. This was followed by nausea, vomiting, very slight abdominal distention, and moderate tenderness in the left upper quadrant. Blood studies were taken, two hours after onset of this episode, which showed: white blood count—16,000; differential—not remarkable; sedimentation rate—44 mm. per hour; total protein—5.85%; hematocrit—31 mm. A plain film of the abdomen showed several markedly distended loops of small bowel. The pain and distention progressively increased. Wangensteen duodenal suction and intravenous fluids were started, and the patient was scheduled for operation. At 7:30 P.M., ten minutes before being taken to the operating room, he gagged on the nasal suction tube. The resulting increased intra-abdominal pressure caused extrusion of several loops of small intestine through the large wound in the left flank, which had been sealed-off by the traumatic colostomy of the descending colon.

Celiotomy was performed immediately. Three markedly dilated, discolored loops of lower jejunum, densely plastered together, were found incorporated in a mass of adhesions In addition, four other loops were found to have been extruded through the large opening in the flank. The abdomen was closed following the liberation of the bowel obstruction and the replacement of the eviscerated bowel. The defect in the left flank was too large to attempt closure. Therefore, it was overlaid by two folded linen towels and gauze packs, held in place by several retention sutures of braided silk, thus, containing the abdominal contents within the peritoneal cavity. The patient's immediate postoperative condition was good.



FIG. 7-A



FIG. 7-B

FIG. 7-A.—Case 24: Traumatic colostomy of descending colon and proximal defunctioning colostomy of transverse colon. Appearance on admission.

FIG. 7-B.—Case 24: Appearance of patient after one-stage operation, resecting descending colon (traumatic colostomy) and transverse closure of proximal colostomy.

Convalescence was uneventful until the 16th postoperative day, at which time a dissecting wound occurred beneath the surgical colostomy which communicated with the wound in the flank. Exploration revealed multiple fecal sinuses in the area because of the retraction of the colostomy. Therefore, May 14, 1945, a revision of the surgical colostomy was performed. On the second postoperative day, patient complained of severe cramp-like abdominal pain and nausea. Examination revealed hyperactive peristalsis and a tinkling bell note just above the umbilicus. A diagnosis of intestinal obstruction was made and confirmed roentgenologically.

Celiotomy was performed immediately. Two angulated loops of small bowel were found densely adherent to the abdominal wall. The obstruction was released; 100,000 units of penicillin in saline were placed in the peritoneal cavity and the abdomen closed in layers without drainage. Plasma, 500 cc. and whole blood, 500 cc. were administered on the operating table. His postoperative course was uneventful until the 18th day, at which time he complained of nausea, anorexia and general malaise. Examination revealed an acutely ill, toxic patient with a moderate icteric tint. Diagnosis of infectious hepatitis was made. The icteric index was 68 and the bromosulfalein test at that time showed 75% retention. Therapeutic measures were instituted until the bromosulfalein test showed no retention.

After the revision of his colostomy all the abdominal sinuses healed. Following barium enema, G. I. series and sigmoidoscopic examination, August 20, 1945, both the traumatic and the surgical colostomy were dissected free from the abdominal wall. The traumatic colostomy was managed by resection of the damaged portion of descending colon and end-to-end anastomosis. The antimesenteric surgical colostomy was closed transversely. The

bowel was replaced within the peritoneal cavity and the abdomen closed without drainage (Fig. 8).

The patient's convalescence was uneventful except that the defect in the left flank did not heal satisfactorily. Therefore, November 5, 1945, the defect was corrected by a plastic repair, including a full-thickness double pedicle graft and a split-thickness graft. Patient made an uneventful recovery.

His end-result was excellent. He regained his normal weight and was completely asymptomatic. He tolerated a regular diet well and had regular, normal bowel movements (Fig. 8).



FIG. 8.—Postoperative barium enema of Case 24. (Same case as in Figure 7.) Showing the result obtained following closure of traumatic colostomy of descending colon and defunctioning colostomy of transverse colon.

Two cases showed complete obstruction of the large bowel. One was due to extreme angulation of the transverse colon with adherence to the anterior abdominal wall following extraperitoneal type of colostomy closure performed overseas. The second case, No. 77, developed obstruction with intussusception of the descending colon due to a large leiomyoma which developed at the site of the spur in a Paul-Mikulicz closure.

This case will be referred to again in discussing colostomy closure. It is interesting to note that no case of either large or small bowel obstruction developed following closure of colostomy or any other large bowel surgery performed at Rhoads General Hospital.

*Associated Severe Abdominal Injuries and Concomitant Extensive*

*Wounds:* An attempt to describe all the concomitant severe injuries is beyond the scope of this paper, and will be impossible in the space allowed. All types of severe, multiple, compound, comminuted fractures, osteomyelitis, extensive nerve injuries, chest wounds, *etc.*, were encountered. Table II gives a partial list of these conditions. Sound surgical judgment was needed frequently to decide which conditions warranted surgical preference. As a rule, colostomies were closed before orthopedic surgery was attempted.

TABLE II

ASSOCIATED INJURIES AND RELATED COMPLICATIONS INCURRED PRIOR TO ADMISSION OR DEVELOPED PRIOR TO LARGE BOWEL SURGERY IN 96 PATIENTS

| Injury or Complication | No of Cases | Per Cen |
|---|---|---|
| Stomach | 6 | 6.3 |
| Small intestine | 30 | 31.5 |
| Liver. | 6 | 6.3 |
| Spleen | 2 | 2 1 |
| Kidney | 6 | 6 3 |
| Bladder | 9 | 9 4 |
| Ureter | 2 | 2 1 |
| Urethra and prostate | 4 | 4.2 |
| Perineum | 9 | 9.4 |
| Fractures | 37 | 38 9 |
| Osteomyelitis and chondritis | 15 | 15 7 |
| Nerve injuries | 9 | 9 4 |
| Thoracic wounds | 10 | 10.4 |
| Intestinal obstruction | | |
| Small bowel—incomplete | 5 | 5 2 |
| Small bowel—complete | 2 | 2.1 |
| Large bowel—complete | 2 | 2 1 |

* All cases of intestinal obstruction occurred prior to surgery performed at Rhoads General Hospital

There was also a multiplicity of associated abdominal injuries which, likewise, cannot be described in detail. These are shown in Table II. It is regrettable that these bare statistics convey little of the drama and wonder of these cases. Such grievously wounded men never before survived their wounds. Prior to this war, cases with similar abdominal wounds would seldom have lived to reach a hospital. Due credit for this achievement must be given to the company aid men's and battalion surgeon's heroic on-the-spot treatment.

By the time these cases reached the General Hospital in the United States, through the normal channels of evacuation, these associated wounds were usually healing or healed. However, their presence markedly influenced the course of treatment. For example, a man who had lost one kidney was considered most carefully before sulfonamides were administered, and watched with great care during the treatment. The presence of extensive, silent retroperitoneal abscesses was another distressing complication in several cases.

*Closure of Colostomy:* Ever since Paul's[2] classic description of the procedure of colonic exteriorization, published in 1895, surgeons have been engaged in a never-ending search for the ideal way to close a colostomy. This technic was first described by Heinecke in 1890, and the first case in which this method was applied was reported by Block,[1] of Copenhagen, two years later. However, the procedure did not gain widespread acceptance until after the later reports of Paul and Mikulicz. Following the appearance of Mikulicz's[3]

paper on the subject, in 1903, and the erroneous but widespread application of his name to the procedure, many variations of the so-called Mikulicz technic have appeared. The use of this technic has been based on the widespread and until recently justifiable fear of peritonitis resulting from soilage of the peritoneal cavity or leakage at the suture line when intraperitoneal anastomosis was attempted. The extraperitoneal technic remained the only safe procedure in colon surgery until after the advent of the sulfonamides.

In 1940, Marshall[7] introduced a relatively nonabsorbable sulfonamide derivative—sulfanilylguanidine. This was originally developed to treat bacterial disease of the intestinal tract. Due to its low degree of absorbability it was expected to exert a strong local bacteriostatic effect. The application of sulfaguanidine to colon surgery was first recognized by Dr. Warfield Firor.[8] In 1941, he first reported its use in a series of 12 cases prepared for colon surgery. In 1941, Poth[9] introduced sulfasuxidine for a similar use. A renewed interest in primary anastomosis of the large bowel followed. It was shown by Firor,[10] Poth,[11] Allen,[12], Archer,[13] and others, that primary resection and anastomosis of the colon could be performed safely after preoperative preparation with sulfasuxidine. In view of this work, it is becoming increasingly apparent that the extraperitoneal technic is no longer the procedure of choice except in a limited number of cases.

When the first group of colostomy patients were admitted to our service, the various methods used to close a temporary colostomy were carefully considered. Certain dangers inherent in the Paul-Mikulicz closure were recognized. Mayo and Schlicke,[14] in 1942, cited the dangers in crushing a colostomy spur. These are perforation of the bowel by the enterotome, with resulting peritonitis; inclusion of part of the mesentery in the enterotome, with resulting gangrene of the spur and perforation; also, hemorrhage from the colostomy if part of the mesentery is included in the enterotome and jejuno- and ileocolic fistulae resulting from intrusion of a loop of small bowel between the limbs of the spur at the time the clamp was applied.

One further complication of the Paul-Mikulicz type of colostomy closure should be mentioned. In this series, two cases were noted who displayed a complication following the crushing of a spur which we have not seen recorded before. One of these cases (Case No. 77), already mentioned, had a large tumor of the bowel develop at the site of a Paul-Mikulicz closure. This was reported by the pathologist to be a leiomyoma. (Fig. 9.)

A second case was later operated upon for closure of fecal fistula resulting from an unsuccessful Paul-Mikulicz closure. In this case, a similar tumor of smaller size was found. It was easily seen in the second case that the tumor represented an hypertrophy of one side of the crushed spur. It is our opinion that the first case represented an extreme degree of this condition. Bargen,[15] in 1944, reported a total of 806 cases of new growths of the large intestine, including only two leiomyomata. A case illustrating leiomyoma follows.

Case No. 77.—This 34-year-old white soldier was wounded in Italy by an 88-mm. shell

fragment, sustaining a wound in the left costal vertebral angle which traversed his abdomen and made its exit in the left lower quadrant.

A celiotomy performed shortly after injury at the field hospital revealed severe laceration of the left kidney and a perforation of the descending colon. A transperitoneal nephrectomy was performed and a colostomy established by exteriorizing the perforation in the descending colon. Two months after injury the patient's colostomy was closed by Mikulicz technic. For the seven weeks during which the colostomy functioned the patient was exceptionally well. However, three weeks after closure of his colostomy he developed an abscess at the site of closure, the wound separated and a large amount of pus escaped. Following this episode, diarrhea developed which at first consisted of only fluid fecal material. Later, a mucoid discharge was seen and, finally, just before evacuation by hospital ship to the States, his diarrhea became bloody.



FIG. 9.—Specimen removed from descending colon in Case 77, showing leiomyoma at site of Mikulicz closure of colostomy. Arrow indicates lumen of bowel above tumor.

Upon admission to Rhoads General Hospital, on April 14, 1945, he complained of an almost continuous generalized cramp-like abdominal pain, which was most marked along the course of the large bowel. He also complained of a stabbing, recurrent pain in the left upper quadrant just above site of closure of colostomy. He was constantly nauseated and took little by mouth for the week prior to admission. He had 15-20 evacuations daily of a small amount of fluid material per rectum, consisting of mucus and bright red blood. He had not passed feces for several days.

Physical examination was essentially negative except for the abdomen. There was little distention. The cecum, ascending colon and transverse colon were palpable and appeared to be filled with feces. There was marked tenderness directly over the site of his colostomy closure and marked guarding of the entire left side of the abdomen.

All his abdominal wounds were healed. This patient was observed for ten days. During this time his nutrition and fluid balance were maintained by intravenous therapy. Barium enema revealed a mass in the descending colon above what seemed to be an ample anastomosis. Sulfaguanidine was administered orally as usual.

On April 25, 1945, a celiotomy revealed a large intrinsic, pedunculated tumor of the descending colon at the site of the previous colostomy. This was removed by resection of a 14-cm. segment of the descending colon. An end-to-end anastomosis was accomplished. Patient's convalescence was uneventful, except that he developed a recurrent phlebitis of the right forearm. Following this surgical procedure all his gastro-intestinal complaints completely disappeared. He had regular, daily, normal bowel movements and had no difficulty with a regular diet. The postoperative barium enema showed a very satisfactory anastomosis.

The microscopic diagnosis of the colonic tumor was fibroleiomyoma.

We set as our goal the restoration of the colon to as near normal anatomic form and function as possible. Our cases were all young men, with many years of life expectancy. We did not wish to have them handicapped by an improperly functioning colon, or an abdominal wall that was inadequate. Under both of these headings the extraperitoneal closure was found wanting. It leaves the patient with a loop of large bowel permanently incarcerated in the abdominal wall.

Even in the presence of an adequate stoma, many patients who have had extraperitoneal closures experience unpleasant abdominal discomfort from tension on the bowel at the point of incarceration, when the bowel is distended, or during defecation. The occurrence of ventral hernia following extraperitoneal closure is common. Babcock and Bacon,[16] in discussing the complications of a Paul-Mikulicz procedure, stated that it usually leaves a weak abdominal wall or hernia. Our own experience with a large group of cases done by this technic overseas coincides with their observation. Finally, it was our considered opinion that the presence of a loop of colon permanently incarcerated in the abdominal wall offered a likely site for the development of an internal herniation and obstruction of the small intestine.

The advisability of intraperitoneal closure was, therefore, considered. Only two factors weighed against this. It exposed the patient to contamination of the peritoneal cavity and probable peritonitis. It involved a more extensive surgical procedure. In view of our previous experience and the work by Firor and Poth, and others, with sulfonamide preparation of the bowel for colon surgery, it was felt that the first disadvantage could be overcome. Since these patients were mainly young adult males the second objection was of lesser importance and the advantages to be obtained outweighed the prolongation of operating time.

In one of the early patients admitted (Fig. 10), a complete rotation of the exteriorized loop, with transposition of the distal and proximal stomata, was observed. A crushing clamp could not be safely applied to this colostomy. Seven cases in this series showed complete rotation. Since many of these colostomies had been set-up in haste, under field conditions, and since they had been established elsewhere, it was evident that the application of an enterotome would usually be extremely hazardous.

It was, therefore, decided to completely free the exteriorized loop from the abdominal wall and perform an intraperitoneal closure. This technic was

followed in every case admitted to Rhoads General Hospital for colostomy closure.

*Sulfonamide Preparation of the Large Bowel for Surgery:* Sulfaguanidine was used in preparation of the bowel for surgery. There were several reasons for the use of this drug rather than the newer drug, sulfasuxidine. Vieta and Stevenson,[17] in 1942, had shown it to be adequately effective in inhibiting and killing coliform organisms. Firor, in 1941, had used it successfully, although he later condemned it in favor of sulfasuxidine. We had used it previously in civilian surgery with satisfaction. Sulfaguanidine was a standard item of issue in the Army Medical Department. Sulfasuxidine, although not denied to us, was not an item of issue. After completing this series we can say that the results obtained with the use of sulfaguanidine were eminently satisfactory.

Vieta and Stevenson, Firor and Poth, have all stated that sulfaguanidine is less effective in the presence of large amounts of pus or extensive ulceration

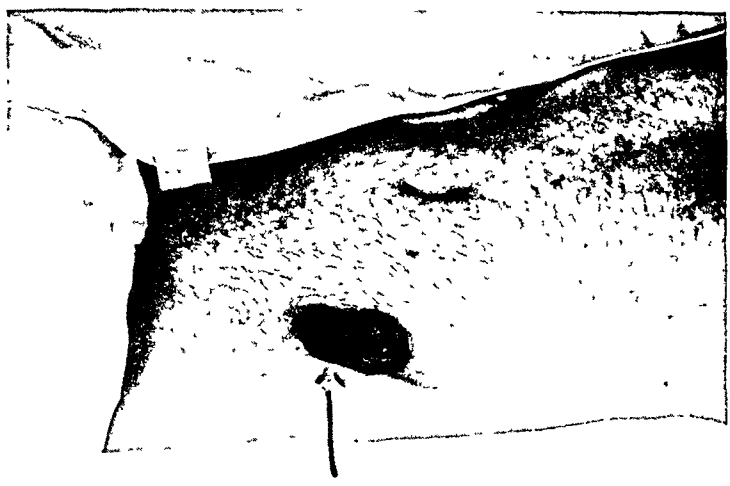


FIG. 10.—Case 46: Illustrating transposition of colostomy stomata. Arrow indicates proximal stoma.

of the colon. This criticism cannot be answered since these two conditions were seldom encountered in these cases. However, Firor and Poth both reported unfavorably on the use of sulfaguanidine on the basis that it had a relatively high degree of toxicity and was not as effective as sulfasuxidine. In our experience this toxicity was not observed. It was administered to about 300 cases, to some for prolonged periods. Only one toxic reaction to the drug, allergic in type, manifested by generalized urticaria, was observed.

It should also be reported that an increased amount of bleeding occurs at operation when sulfaguanidine is used. This was explained by Vieta and Stevenson to be due to a reduction in the level of the plasma prothrombin, by decreasing the number of organisms of the normal intestinal flora, thereby reducing the synthesis of vitamin K. However, if this is true of sulfaguanidine, it should be equally true of sulfasuxidine and sulfathaladine. This

observation led to the administration of parenteral vitamin K to all patients prepared with sulfaguanidine.

The work-load carried by the laboratory of Rhoads General Hospital during the period covered by this series was so heavy that quantitative bacteriologic studies on all cases was not justifiable. However, cultures were taken from the colostomy stomata of 26 consecutive cases at the time of operation. The cultures were taken from the proximal and distal stomata at a depth of at least two inches. Two cultures showed no growth, nine showed an absence of coliform organisms and, in the remainder, coliform organisms were present.

Theoretically sulfasuxidine should be eminently more effective as a non-absorbable sulfonamide than sulfaguanidine in preparation for colon surgery since the absorption rate is 5% and 50%, respectively. However, sulfaguanidine may possess some special antibacterial activity as yet unexplained. The greater absorption of sulfaguanidine may be responsible for greater safety, in that the drug is not only concentrated within the lumen, but also in the wall of the bowel, as well as in all the intra-abdominal tissues. It is interesting to note that, as reported by Marshall in 1940, sulfaguanidine is equally as effective as sulfapyridine in the treatment of pneumococcic infections in mice and only somewhat less effective than sulfanilamide in the treatment of *B.-hemolytic Streptococcic* infections. In conclusion, as to the comparative efficacy of sulfaguanidine, sulfasuxidine and sulfathaladine, it should be clearly understood that no attempt was made to evaluate the advantages or disadvantages of the latter two. However, it is our conviction that sulfaguanidine, although shelved in favor of newer and reputedly more efficacious sulfonamides, is a very efficient and reliable chemotherapeutic agent in the preoperative management of colon surgery. It has served us exceedingly well.

### PREOPERATIVE WORK-UP

The preoperative work-up of patients includes the following procedures:

1. A periodic complete blood count and urinalysis.
2. Preoperative determination of blood chlorides and proteins.
3. Roentgenograms of chest.
4. Barium enema and small bowel series.
5. Bacteriologic studies of all open wounds.
6. Sigmoidoscopic examination.

Following admission and during the work-up, patients were put on a low residue, high caloric, high vitamin diet.

In the preoperative work-up of these patients the importance of a barium enema, small bowel series, and sigmoidoscopic examination cannot be stressed too strongly. A small bowel series often revealed areas of fixation of the small intestine which was of importance in prognosis, operative approach and postoperative management (Case No. 57). It revealed congenital anomalies as in Case No. 81, in which the entire small intestine lay to the right of the entire colon, which was entirely confined to the left half of the abdomen (Fig. 11).

The small bowel series frequently showed evidence of severe vitamin deficiency. Barium enema, of course, delineates the continuity of the colon. It reveals before operation whether or not a spur had been set-up. It is particularly helpful in multiple colostomies, as it can be determined thereby whether both colostomies can be closed at a single operation, by removal of the intervening loop and an end-to-end anastomosis. A roentgenologic finding of interest in this regard is that the defunctioned intervening loop between the two colostomies may take on the roentgenographic appearance of small intestine (Fig. 12).



FIG. 11.—Case 81: Congenital anomaly of the colon. Colostomy performed at apex of colonic loop. Extraperitoneal closure overseas. Developed fecal fistula. Closure of fecal fistula at Rhoads General Hospital. Illustration shows preoperative barium enema.

Sigmoidoscopy is of value in determining the patency and degree of healing of the rectum and rectosigmoid, particularly when that portion of the bowel was damaged. It should be noted that when a colostomy is established below the midsigmoid, the distal loop is usually so fixed between the abdominal wall and pelvic peritoneal reflection that it is impossible to advance the scope beyond the angulation at the point where the rectosigmoid leaves the hollow of the sacrum. This is not evidence of obstruction or narrowing and can be so determined by barium enema. It should be noted that this finding may occur in a normal individual without colostomy.

*Preoperative Preparation:* Ten days prior to the tentative date of closure

the patient was put on a special soft, low residue diet and the following measures initiated:

1. Two grams of sulfaguanidine were administered orally four times a day until the morning of operation.

2. One gram of sulfaguanidine was inserted into the distal loop in two perforated capsules three times a day.

3. The distal loop was irrigated three times a day with 1:10000 solution of acriflavine.

FIG. 12-A

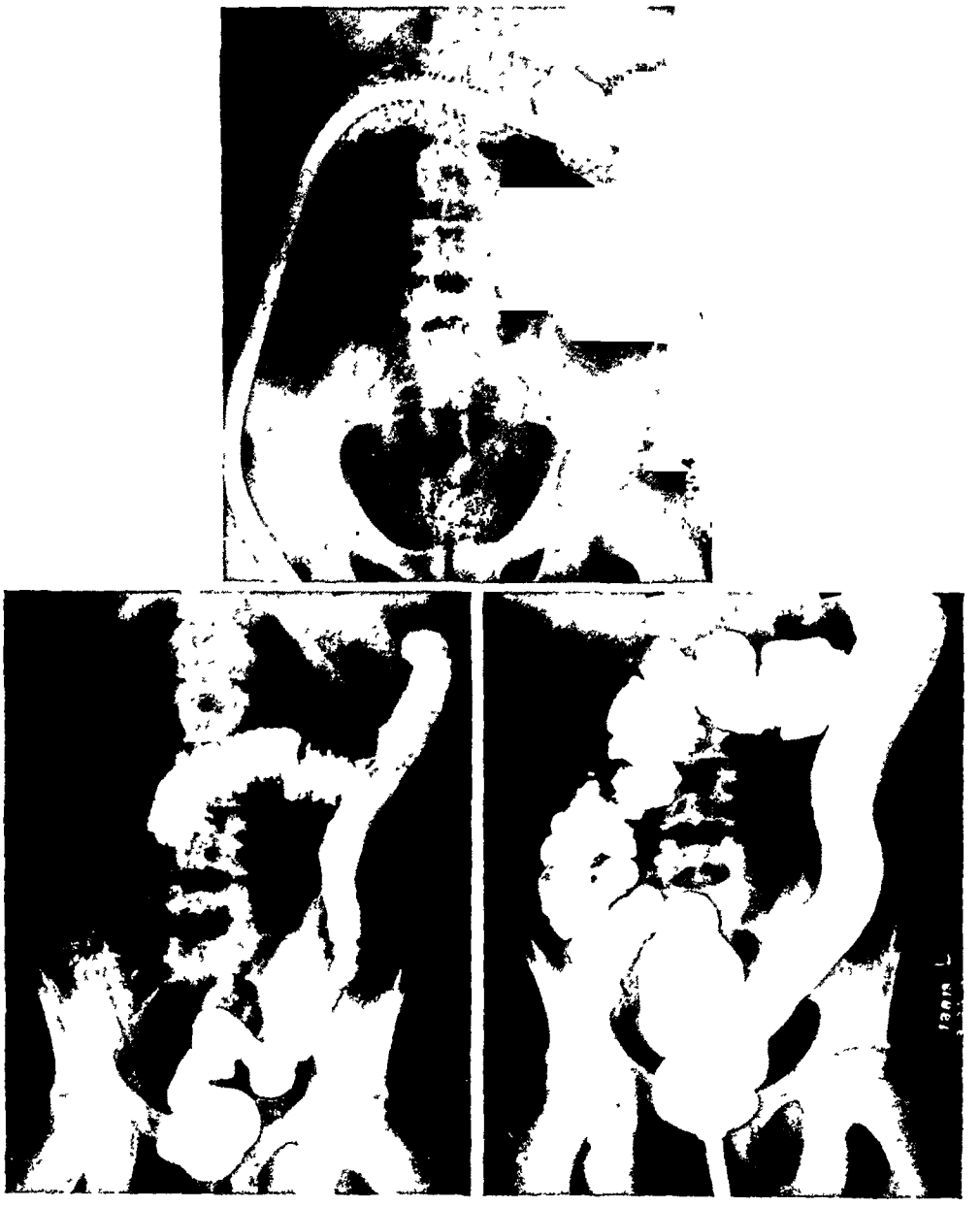


FIG. 12-B

FIG. 12-C

FIG. 12-A.—Case 50: Defunctioned segment of colon between two colostomies of transverse colon showing appearance simulating small intestine.
B. Case 50: Barium enema of same patient following closure of distal colostomy.
C. Case 50: Barium enema of same patient after closure of both colostomies.

4. Three days before operation the patient was put on a milk and jello diet with supplemental fluids to maintain a 3,000 cc. daily intake.

5. Vitamin K was administered parenterally in amounts of 2 mg., three times a day, for two days preoperatively.

6. The day before operation the patient received nothing but water by mouth.

7. One thousand cubic centimeters of 10% glucose in distilled water and 500 cc. of plasma, or 30 Gm. of parenteral amino-acids were given intravenously.

8. At 7 A.M. and 3 P.M., he received saline cathartics.

9. At noon and at 8 P.M., both loops of the colon were irrigated with acriflavine until the solution returned clear. This irrigation was repeated at 6 A.M. the morning of operation.

*Operative Technic:* These cases were usually given gas-oxygen-ether anesthesia. However, spinal anesthesia was used in a fair percentage of the cases (Table III). Following anesthetization, the abdominal wall, including the exteriorized stoma, was prepared with ether, alcohol and tincture of merthiolate or mercresin. A small operative field was draped in the usual manner.

An elliptical incision was made about the exteriorized colonic stoma. This incision was usually made in the direction of, and large enough to include, the old scar. However, when the colostomy had been established through the original celiotomy wound, only enough scar was excised to free the bowel. A cuff of skin and subcutaneous tissue 0.5 cm. in width was left attached to the bowel on either side. By sharp dissection, the incision was then carried down to the fascia, completely around the bowel. By combined sharp and blunt dissection, the fascia and muscles were completely dissected from the colon. The peritoneal cavity was entered with care and the loop of bowel completely freed from the abdominal wall. No fascia or muscle tissue was left attached to the bowel. The loop of colon was then drawn outward upon the abdomen, if possible. The loop was thoroughly inspected to determine whether or not a spur had been set-up and to detect any damage to the bowel in freeing it from the abdominal wall. The free peritoneal cavity was protected by sponges. If the colostomy was the simple antimesenteric type without a formed spur, or with a spur which could easily be broken down without injury to the bowel or embarrassment to the circulation, the skin cuff was then excised from the edges of the stoma. The everted mucosa was freed and replaced, the edges of the defect freshened and a simple transverse closure effected, using an inner continuous Connell suture of No. 000 chromic catgut and an outer layer of interrupted fine black silk sutures (Fig. 13).

If the colostomy displayed a complete transection of the bowel, or if a very firm and extensive spur was present, both ends of the bowel, including the complete spur, if present, were resected. It should be emphasized that it is necessary to resect any spur which cannot be satisfactorily broken down. To leave in a fixed spur at the site of closure results in a rigid defect with faulty

peristalsis and a narrowed lumen, and produces malfunction and unpleasant abdominal symptoms.

An end-to-end anastomosis was then performed, using an inner continuous suture of No. 000 chromic catgut and an outer layer of interrupted fine black silk sutures. In the first 12 cases of end-to-end anastomoses, a Furniss clamp was used to accomplish a closed anastomosis. However, the inconsistency of operating in the field of an open colostomy stoma and then doing a closed

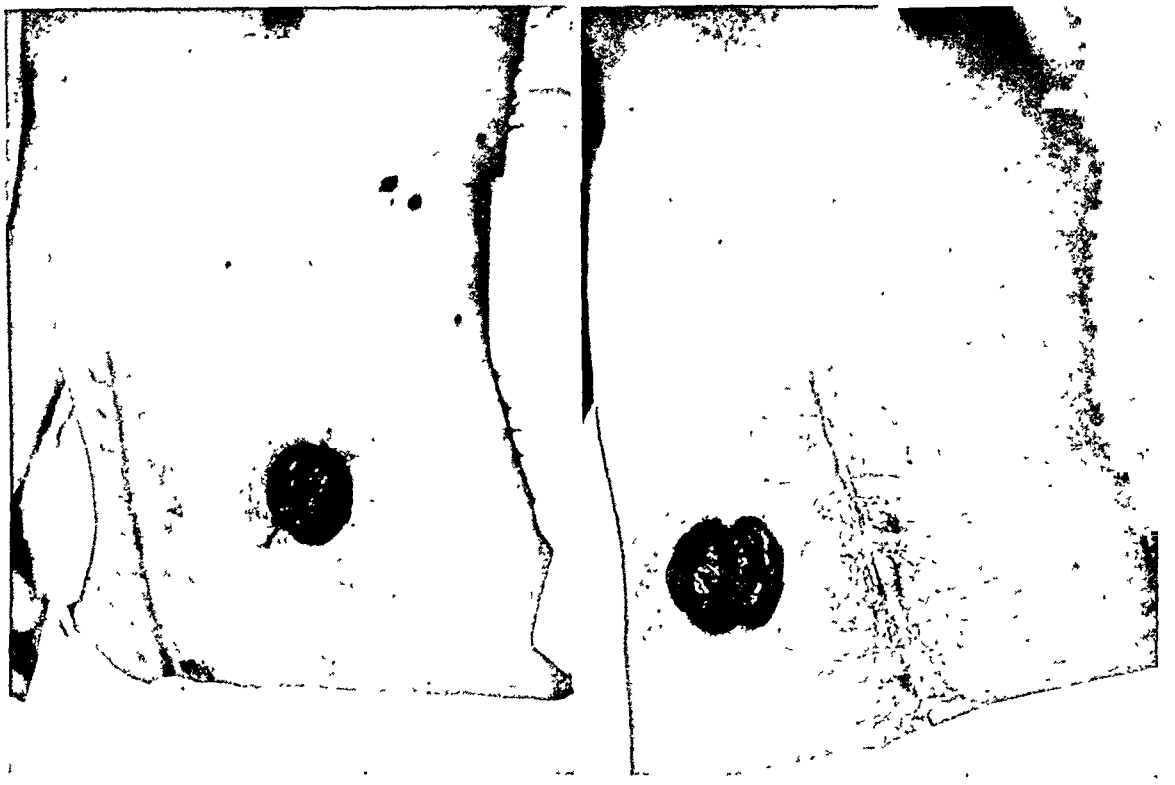


FIG. 13-A FIG. 13-B

FIG. 13-A.—Temporary colostomy performed by simply exteriorizing damaged segment of colon. (Antimesenteric colostomy).
B. Temporary colostomy showing complete trans-section of colon for defunctionalizing injured distal colon.

anastomosis was soon recognized. Thereafter, in the remaining cases, the bowel was resected using Doyen clamps with the electric cautery and an open end-to-end anastomosis performed (Table III). After the anastomosis was completed, the defect in the mesentery was closed. The bowel was then replaced within the peritoneal cavity. Any adjacent small bowel denuded of serosa was repaired. In two cases, this entailed the resection and end-to-end anastomosis of a damaged segment of small intestine. Five grams of sulfanilamide was placed about the colon anastomosis before the abdomen was closed.

The abdominal wall was closed in layers, using catgut throughout, except for the skin, which was closed with interrupted black silk sutures. All cases were closed tightly without drainage. As a rule, after proper preparation, peritoneal contamination, which could result in peritonitis, was given little

consideration. It is evident, from this description of the operative procedure, that we pushed the usefulness of the technic of preoperative preparation of the colon with sulfaguanidine to the utmost by treating all colon operations as though they were clean surgery.

TABLE III

INTRAPERITONEAL LARGE BOWEL OPERATIVE PROCEDURES

| | |
|---|---|
| Resection and anastomosis | 42 |
| Open technic | 30 |
| Closed technic | 12 |
| Resection and ileotransverse colostomy (open) | 6 |
| Transverse closure of antimesenteric colostomy | 41 |
| Transverse closure of colonic fistulae | 19 |
| Anaesthesia | |
| Gas-oxygen-ether | 70 |
| Spinal | 38 |
| Total | 108 |

The management of large bowel surgery as if it were clean surgery merits further emphasis. This may well be exemplified by citing a case of volvulous of the sigmoid, with obstruction, for which a colostomy had been performed overseas, subsequently admitted to our service. In our operative treatment of this case, the abdomen was first opened through an oblique incision in the left lower quadrant. Exploration revealed a markedly redundant loop of sigmoid, in the apex of which there was an antimesenteric colostomy. The incision in the left lower quadrant was then temporarily closed with towel clips. The colostomy, which had been established above the umbilicus, was then freed from the abdominal wall by our usual technic and dropped into the peritoneal cavity. This incision was then closed in layers. The abdomen was then reentered through the initial incision in the left lower quadrant, through which the colostomy was now withdrawn and a resection of a segment of the sigmoid colon, 14 inches in length, bearing the colostomy stoma, was performed.

An open end-to-end anastomosis was then accomplished. The abdomen was closed without drainage. It is very apparent that during this extensive surgical procedure, in the face of an open colostomy which was freely manipulated and carried through the larger part of the peritoneal cavity, contamination was extensive and unavoidable, yet the postoperative course was entirely uneventful and without the slightest evidence of peritoneal irritation.

*Postoperative Management:* One of the most essential factors in the postoperative care of these cases was oral starvation. The patients were given nothing by mouth the day of operation. They received 5% glucose in saline, or 10% glucose in distilled water, as indicated.

On the first postoperative day, the patient was allowed water, tea and ginger ale. Sulfadiazine was started orally, beginning with an initial dose of 2 grams and continuing with one gram every four hours, together with 2 grams of sodium bicarbonate. This was all the oral intake the patient was allowed for the first four to five postoperative days. His daily caloric, fluid and vitamin

requirements were met by intravenous therapy. Parenteral amino-acids were given to allow the patient 30 Gm. of protein daily. Vitamin K was administered parenterally in amounts of 2 mg., three times a day, for two days postoperatively. Vitamin C and B-complex were administered in adequate amounts.

By following this regimen, the amount of postoperative distention was kept to a minimum. Wangensteen decompression was used postoperatively in only ten cases, or 9%.



FIG. 14-A FIG. 14-B

FIG. 14-A.—Barium enema performed 18 days after intraperitoneal anastomosis. Arrows point to anastomosis.
B. Barium enema of same patient 28 days after operation, showing marked dilatation in ten days.

The significance of oral starvation may be more fully appreciated if it is remembered that the most significant factor in intestinal distention is swallowed air. Wangensteen[18] concluded that about 68% of gas in the intestine in obstruction has its origin in swallowed air; about 23% from nitrogen in the blood passing into the intestine; and that less than 10% of all the gas forms from putrefaction and fermentation. It has been observed that the amount of swallowed air taken with fluids is minimal compared with that swallowed with solid foods.

Oil retention enemata were started on the 2nd postoperative day and continued daily. By the 2nd postoperative day, practically all patients were passing flatus per rectum.

On the 5th or 6th postoperative day, jello, bouillon and toast were added to the patient's oral intake. From this point on, the diet was gradually built up to a soft, low residue diet by adding one item of food at a time until the full diet was reached by the 14th postoperative day.

The patient's dressing was not disturbed until the 7th postoperative day, at which time the wound, as a rule, was found clean and well-healed. Sutures were removed on the 10th postoperative day. The patient was allowed out of bed on the 14th postoperative day, at which time the wound was again inspected and the dressing discarded.

Sulfadiazine, which had been started on the 1st postoperative day, was continued until the 14th day. In this respect, our postoperative management differs radically from other surgeons who have been doing colon surgery and placing reliance on preoperative preparation with the sulfa drugs of low absorption. Most reports by these men have shown that they continued with a nonabsorbable sulfonamide in the postoperative period. In our regimen, an absorbable sulfonamide—sulfadiazine—was used postoperatively because it was felt that maintenance of a high sulfa level in all the tissues is of more importance during this period than merely decreasing the intestinal flora.

Postoperative laboratory work included blood count, and sulfa level every other day; and daily urine analysis. Plasma proteins were checked as indicated.

Two cases which showed evidence of localized peritonitis were given streptomycin, with gratifying results.

A re-check barium enema was obtained four weeks after operation. An anastomosis measuring 1 cm. or more at this time was considered adequate. In a few instances, a barium enema was obtained on the 18th postoperative day. This was usually found to show a narrowed anastomosis which dilated unbelievably in the next ten days (Fig. 14).

All patients in this series showed an adequate functional anastomosis and were symptom-free at the time of their discharge.

## RESULTS

Our results were summarized in Table IV. In all, 92 cases with colostomies or fecal fistulae were closed. Ninety of these were performed for wounds of the colon and rectum, two for other reasons. Three other nonbattle casualties had resections and ileocolostomies performed, also using the open intraperitoneal technic. A total of 108 large bowel operations were performed. No fatalities occurred in this series. All cases showed satisfactory bowel function upon discharge. The complications were few and remediable.

Fecal fistulae developed in three cases. Two of these closed spontaneously within ten days. Only one of these three cases had a persistent fistula, requiring operation. Therefore, complicating fecal fistulae requiring surgical correction occurred in only one case, or an incidence of 0.9%. There were nine cases of wound infection, including the three fistulae mentioned above, or 8.4%. Four cases developed a ventral hernia at the site of closure. These were cases where the colostomy had been exteriorized through a large wound which showed a defect in the abdominal wall at time of closure. There was clinical evidence of a localized peritonitis in two cases, or 1.8%. Neither of these cases developed fecal fistulae, and their signs and symptoms of peritoneal irritation cleared within four to five days.

TABLE IV

RESULTS—OBTAINED IN 108 INTRAPERITONEAL COLON OPERATIONS

| | No. of Cases | Per Cent |
|---|---|---|
| Total anastomoses and closures | 108 | |
| Excellent results (determined by barium enema) | 102 | 94.4 |
| Adequate result | 6 | 5.6 |
| Bowel function: | | |
| Normal | 106 | 98.1 |
| Adequate | 2 | 1.9 |
| Wound infections (including fecal fistulae) | 9 | 8.3 |
| Fecal fistulae | 3 | 2.7 |
| Spontaneous closure (within 10 days) | 2 | 1.8 |
| Requiring surgical closure | 1 | 0.9 |
| Localized peritonitis | 2 | 1.8 |
| Ventral hernia | 4 | 3.7 |
| Mortality | 0 | 0.0 |

These results compare most favorably with the results of the few other groups reporting similar work.

Dixon and Benson[19] reported 102 cases of colostomy closure. Their operative technic was not exactly similar to ours, although they opened the peritoneal cavity to free the limbs of the spur, they did not drop the loop back into the free peritoneal cavity in most of the cases. They reported fecal fistulae in 2% of 102 cases, and wound infection in 13%. They used subcutaneous drainage.

Colonel C. H. Keene,[20] at Lovell General Hospital, as reported by Poth,[11] in June, 1944, in a smaller series of 50 cases, had no fecal fistulae. In Keene's own earlier report it appeared that his technic was nearly the same as ours, except that he did not close the skin for 48 hours postoperatively.

In marked contrast to these excellent results are those reported by Shallow, Eger and Tourish,[21] who used an extraperitoneal closure. They recently reported on 75 cases of colostomy closure, in which fecal fistulae developed in 13.3%.

Pilcher and Nadeau[22] reported on 15 extraperitoneal closures of temporary colostomies for war wounds. Their cases developed fecal fistulae in 6.6%.

Most surgeons who favor extraperitoneal closure stress the comfortable postoperative course of their patients, usually likening their convalescence to that of a postoperative appendicectomy or herniorrhaphy. The same comparison is valid in this series. All but five of our patients were out of bed on the 14th postoperative day. The great majority needed no analgesics after the 5th postoperative day. All but three of these patients left the hospital on a 30-day furlough four weeks after operation, unless requiring plastic repair of the abdominal wall or treatment for unrelated conditions. Following their return from this furlough they were reëxamined and discharged from the hospital. Re-check barium enema at the time of discharge revealed that all but two had an anastomosis measuring over 1.5 cm. in diameter (Fig. 15). These two cases were asymptomatic and had satisfactory bowel function. The re-

maining 95 patients showed excellent anastomoses on barium enema, all were symptom-free and had normal bowel function at the time of discharge.

## DISCUSSION—APPLICATION TO CIVILIAN SURGERY

As previously stated, the first milestone in modern colon surgery was the work of Heinecke, Block, Paul and Mikulicz. The development of the extraperitoneal resection allowed surgeons, for the first time, to attack disease of the colon with a degree of safety.



FIG. 15.—Postoperative barium enema following intraperitoneal anastomosis showing excellent result at time of discharge. Arrows indicate site of anastomosis.

The next advance in surgery of the large bowel was the development by Rankin[23] of the obstructive resection. By use of this technic the segment of colon containing the tumor, its entire mesentery and all involved nodes, could be removed at the initial operation. This accomplished a far more thorough eradication of the disease and resulted in a higher percentage of cures.

The third milestone in modern colon surgery was the development of the principle of defunctionalization. No discussion of colon surgery would be complete without reference to the work of Sir Hugh Devine.[24] In 1939, his article on defunctionalization of the colon was published in this country. In the same article, he described a somewhat different method of performing a

colostomy. Entirely too much emphasis has been placed on Devine's technic of performing a colostomy. The principle of defunctionalization was the important phase of the work. This principle, although realized in part by many surgeons, had never been completely grasped up to that time.

FIG. 16-A



FIG. 16-B

FIG. 16-A.—A Devine-type colostomy performed to defunction distal large bowel with rectal perforation.
B. Same patient following closure of colostomy by intraperitoneal anastomosis.

Next to the contribution of the nonabsorbable sulfa drug, defunctionalization is the outstanding advance in colon surgery in the last half century. The principle of defunctionalization was proven of value in this war, time and again. In many cases who had extensive damage to the distal colon and rectum, which could not be exteriorized, a proximal defunctioning colostomy frequently saved the patient's life, reduced the morbidity, and made later surgical repair easier. Frequently, these distal lesions had completely healed by the time the patient had arrived in the United States. It was thus possible to close the colostomy shortly after admission. Of this principle there can be very little criticism. However, there is much to criticize in the so-called Devine colostomy (Fig. 16).

In this series there were three patients who had Devine-type colostomies. First, let it be said that these functioned satisfactorily. The Devine colostomy can be closed by intraperitoneal resection and anastomosis almost as easily as any other colostomy, but it has several disadvantages.

Babcock and Bacon[16] listed the disadvantages of the Devine colostomy, although they apparently failed to grasp the importance of defunctionalization. They stressed the danger of the Devine colostomy when the transverse colon is tense and thinned by distention. There is also the possibility of perforating the bowel when suturing the limbs of the loop under similar conditions of distention. Contamination of the peritoneal cavity and subcutaneous fat when the bowel is divided is also a danger. They also pointed out that the two stomata do not close spontaneously following crushing of the spur, as Devine claimed usually happened, but frequently needed an extensive surgical procedure to close.

Berman,[25] in addition to the above objections to the Devine colostomy, pointed out that the Devine procedure is fairly lengthy. In a completely obstructed, debilitated individual it may be more than the patient can stand. After the establishment of the Devine colostomy later surgery on the transverse colon is extremely difficult.

The Devine colostomy, notwithstanding its unusual features, closed in the usual way with the Devine or Oschner clamp, has all the disadvantages of the ordinary extraperitoneal closure. It leaves a loop of bowel permanently attached to the abdominal wall, with subsequent danger of obstruction, abdominal discomfort and development of ventral hernia. This series amply illustrated that the well set up double-barrelled colostomy with complete transsection of the bowel adequately defunctioned the distal colon. The technic which the authors used was to exteriorize a loop of bowel through a 9-cm. incision, suturing one limb in either angle of the incision, and suturing the abdominal wall, including about 4 cm. of skin between. Either this colostomy or the typical Devine colostomy can be easily closed by the technic of intraperitoneal anastomosis.

The work initiated by Firor on the use of the nonabsorbable sulfonamides in colon surgery represents the fourth, latest and greatest milestone. Since his initial report, it has been demonstrated repeatedly that the relatively non-

absorbable sulfonamide compounds alter and decrease the bacterial flora of the intestinal tract. The use of this bacteriostatic preparation of the bowel has enormously increased the scope of colon surgery.

Allen[12] has reported on the successful use of sulfasuxidine and sulfathaladine in performing colon surgery, including open anastomoses.

Archer and Lehman[13] reported 36 successful operations performed upon the colon using sulfasuxidine. They reported one death.

The excellent report by Dixon and Benson,[19] similar in many ways to our own work, has already been mentioned.

In 1945, Behrend[26] stated that the use of sulfonamide preparation of the colon has allowed him to practically eliminate the use of the Paul-Mikulicz procedure.

Despite these reports, many excellent surgeons still prefer two-stage, extraperitoneal procedures. In June, 1944, Cattell[27] stated that he considered intraperitoneal anastomosis the greatest hazard to colon surgery and felt that it was unnecessary.

It would seem, however, that a rational approach to the problems of colon surgery at the present time calls for a utilization of all the technics available to the surgeon. There will undoubtedly be some cases in which an obstructive resection will be the procedure of choice. In other cases, a period of defunctionalization will be the best solution to the problem, but undoubtedly, in the majority of cases, preparation with sulfonamides and the performance of resection and primary anastomosis will be the procedure of choice.

In applying the experiences gained in performing colon surgery on battle casualties, several procedures of value should be stressed.

In the occasional case of trauma to the colon encountered in peace-time, the same technic should be followed that has proven so successful during the war. A temporary colostomy should be performed without hesitation.

In penetrating injuries to the rectum a defunctioning colostomy should be performed. The same procedure will often be found of value in extensive repair of the anal sphincter and in plastic operations on the perineum.

The treatment of persistent rectovesical fistula may also be materially facilitated by the performance of a defunctioning colostomy.

In the treatment of complete obstruction of the large intestine, as by a carcinomatous lesion, a defunctioning colostomy performed before primary resection and anastomosis may frequently be the treatment of choice.

Colostomies, in general, should be closed by intraperitoneal anastomosis.

In this presentation certain modifications in the pre- and postoperative management and the surgical technic described are important, and are contributions of value in colon surgery. Although no major innovation has been described, we have gone further in demonstrating the singular efficacy of preoperative preparation with the nonabsorbable sulfonamides and the use of primary large bowel intraperitoneal anastomosis. We have pushed the usefulness of this technic to the utmost by treating all colon operations as though they were clean surgery from start to finish.

In conclusion, it should be stressed that the additional safety produced by the use of the nonabsorbable sulfonamides does not excuse the surgeon from continuing to exercise excellent surgical judgment and technic. The patient should be worked-up as thoroughly and prepared as carefully for operation as before. During the operation, meticulous dissection, careful hemostasis and gentle handling of tissues are as important as ever. In brief, the use of sulfonamides is not a substitute for surgical training.

SUMMARY

The problems of definitive surgery of the large bowel following war wounds have been presented. The mandatory use of a temporary colostomy, as directed by the Surgeon-General, was of utmost importance in lowering the mortality rate in wounds of the large bowel, anus and perineum.

The problems confronting the surgeons in Army General Hospitals in the United States engaged in reparative surgery of the large bowel have been described.

Consideration has been given to the repair of all types of colostomies, including multiple colostomies, wounds with marked loss of substance of the colon, fecal fistulae, trans-sacral perforations of the rectum, rectovesicocutaneous fistulae, and lacerations of the anal sphincter. The methods of repair for each have been indicated.

The problem of closure of colostomy has been discussed at length. The disadvantages of the so-called Paul-Mikulicz closure have been cited. Two cases of leiomyomata of the colon, developing at the site of a spur, have been reported. The advantages of intraperitoneal closure following preparation with sulfaguanidine have been presented. All our cases were treated by this method.

Preoperative preparation consisted of sulfaguanidine therapy, dietary regulation and daily irrigations of the colon.

Our operative technic included the following steps: The bowel was dissected completely free from the abdominal wall, thus entering the peritoneal cavity. An open anastomosis was performed, using a two-layer closure, the inner of continuous catgut, the outer of interrupted black silk. The bowel was replaced within the peritoneal cavity and sulfanilamide placed about the site of anastomosis. The abdomen was closed without drainage.

Postoperatively, the patients were treated by oral starvation, parenteral feeding, and oral administration of sulfadiazine. This last step is at variance with the procedure followed by other groups reporting the use of the nonabsorbable sulfonamides in colon surgery. Other groups have continued with the use of sulfasuxidine postoperatively, whereas we feel that the use of the absorbable sulfadiazine is preferable.

The results obtained in a series of 108 colon operations by this method are recorded. Fecal fistulae requiring surgical correction developed in 0.9% of the cases, and wound infection in 8.4%, including the fecal fistulae. Satisfactory bowel function was obtained in every case.

The importance of the principle of defunctioning the colon in certain cases has been stressed. The Devine colostomy has been criticized. The application of this work to civilian surgery has been considered. Preoperative preparation of patients with the nonabsorbable sulfonamides has made primary resection and anastomosis of the colon as safe as staged operations. The use of this technic has greatly increased the ability of the surgeon to eradicate colonic disease.

In this series a selected technic of preparation for and management of colon surgery, which differs in several important respects from routines reported by other surgeons, was employed. We tested the usefulness of this technic to the utmost by successfully treating all our large bowel cases as clean surgical procedures.

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# EARLY AMBULATION IN ABDOMINAL SURGERY*

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EARLY AMBULATION in abdominal surgery is not a new procedure. It dates from a paper of Ries[1], in 1899. It is really as old as abdominal surgery, however, for Ephriam McDowell after the first ovariotomy on Jane Todd Crawford found her up and making her bed on the fifth postoperative day. The method found rather wide acceptance in European clinics,[2-4-13-14-16-20-21-23-27] but made no substantial progress in this country until the last six years. Recent reviews by Leithauser[35] and Newburger[36] and articles by Powers,[45] Schafer and Dragstedt,[51] and Elman,[42] as well as others,[31-32-38-40-41-42-48-49-50-56-61-62-63-65] have focussed attention on the subject. Nevertheless, there still persists a certain deep-rooted scepticism.

On examining the issue, it is apparent that the chief purpose of bed rest following abdominal surgery is to put the affected parts at rest. This is based on the conviction that inactivity is necessary for optimal wound healing. To secure this advantage it is necessary to accept the disadvantage of prolonged bed rest. Much attention has been directed at various physiologic aspects of the problem. In the recumbent position there is a decrease in vital capacity, and this is further augmented after abdominal operations[54] by a decrease in diaphragmatic function and a relative fixation of the diaphragm in a high position. Moreover, the horizontal position[55] greatly decreases the efficiency of the cough reflex. Under such circumstances some degree of atelectasis is inevitable. The influence of atelectasis, and its amelioration by early ambulation has been studied by Schafer and Dragstedt.[51] They approached the problem by comparing the postoperative temperature curves of 40 early-rising patients, and 100 traditionally bed-confined patients. In practically every instance the early risers had a lower temperature elevation and resumed a normal temperature level sooner than did the bed-confined patients. The assumption of the standing position and the downward pull of the abdominal contents lowers the diaphragm and increases the efficiency of the cough reflex. Coughing in the standing position will almost invariably expel the mucus and aerate the collapsed areas.

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Leithauser[35] has shown that with early rising the vital capacity returns to normal in half the time required by the bed-confined postoperative patients.

Backer-Grondahl[53] followed the spirometric curve of 24 patients upon whom gastric resection was performed for ulcer and found that in the early risers the spirometric curve returned to normal much sooner. His pulmonary complications in a large series were reduced to one-third of their former frequency. In Russia, Kimbarovskiy[20] decreased pulmonary complications from both gynecologic and gastric operations to approximately one-tenth through early rising. In this country a reduction in pulmonary complications has been noted by practically all who have considered the subject[33-35-44-45-51-52-61].

In the uncomplicated postoperative state there is an impairment of the circulatory reflexes necessary to the maintenance of the erect position. This results in cerebral anemia, with its familiar symptoms of faintness, giddiness, visual disturbances, palpitation and deepened respiration. The physiologic mechanisms involved in this syndrome are complex and have been studied extensively as a part of the war program on convalescence and rehabilitation. Among them are a diminished cardiac output,[57-58-59-60] a venous pressure deficit, a blood volume deficit and a decrease in the reserve of the venopressor mechanism. Among the prime causes of this physiologic disturbance is recumbency. The longer it persists, the slower the convalescence. Early resumption of the upright position produces a rapid return of the circulation to normal and is the secret of early postoperative fitness.

A diminished venous return and stasis in the deep veins of the leg are of prime importance in the development of postoperative thrombo-embolic phenomena. There are other elements to be considered, however, such as avoidance of trauma to veins, infection, alterations in the blood, as well as climatic and seasonal influences. Thrombo-embolism starts early, and for ambulation to be effective it must be early and active, that is, within the first 24 hours. In any series of cases there are some in which this cannot be accomplished. For this reason, early ambulation cannot entirely eliminate thrombo-embolic disease. The extensive literature[8-24-25-29-30-35-37-39-44-45-47-61-62-64] on this subject indicates that it probably reduces its incidence. This conclusion may be debatable, however, and final judgment must rest on a statistical analysis of controlled material.

The fear of faulty wound healing is the greatest deterrent to the acceptance of early ambulation. All authors are clear and definite that wound-healing is not impaired and there are many suggestions that it is improved. Ries[1] says: " . . . and I have yet to see the first hernia." Leithauser[33] had no dehiscence or postoperative hernia in 436 cases. In his later report,[35] dehiscence, incisional hernia and recurrences following herniorrhaphy were not more frequent after early rising. There was no instance of eventration in the 900 cases. In 462 abdominal incisions Nelson[43] had three partial disruptions, two of which occurred in patients whose wounds had been closed

with catgut and for whom early ambulation had not been authorized. Powers[45] allowed 39 herniae to rise early, and none recurred. In 39 controls treated by the traditional method of bed rest there were two recurrences. Ashkins[47] noted one bulging cholecystectomy wound and one weak scar, without protrusion, in 823 cases; Schafer and Dragstedt[51] in 102 cases had one eventration and two postoperative herniae. Elman[52] had no wound disruptions in 79 cases, but noted three in his control group. Many others testify in the same vein.[3, 5, 6, 7, 9, 10, 11, 12, 15, 17, 18, 19, 22, 26, 28]

From an experimental point of view, Newburger[36] produced standardized celiotomy wounds in rats and at intervals of 3–5–10 days the strength of the wounds was determined in animals which were kept at rest and in others which were exercised. Exercise rather than immobilization was found to hasten the increase in tissue strength of the experimental abdominal incision.

The Russian, Kimbarovskiy[29] studied wounds in dogs in the ambulant state and dogs forced into the reclining position by means of plaster encasements. In the restricted animal he concluded there was a decrease in fibroplasia.

The experience and data presented in this paper cover all cases admitted to the Surgical Service at the Brooke General Hospital, Fort Sam Houston, Texas, during the period September 1, 1943 to August 1, 1945. This was one of the larger Army General Hospitals and was situated on a permanent post. The material was predominantly military but there is included a very sizable number of veterans, dependents and retired personnel. The plan of early ambulation in this hospital was inaugurated by Brigadier General James Bethea during his tour as Chief of the Surgical Service. He was succeeded by Doctor J. M. Foster who continued these policies until he was relieved on the activation of the Colorado Unit.

All cases were under our direct supervision or personal care. The Service was so arranged that each case was seen each day by one of us during the immediate postoperative period. All were carefully examined on discharge. The data were obtained from the statistical records of the Surgical Service and from various personal notes and memoranda.

In all, there were 2827 abdominal cases. Nine hundred and nineteen of these were some variety of hernia. All herniae were treated by early ambulation from September 1, 1942 to July 13, 1943. During this period the policy was highly satisfactory and no ill effects were noted. Only one recurrence was noted at the Hospital. Two others were reported by letter. The exact date of recurrence in these cases can never be determined. Certainly, none recurred within six weeks after operation. There were no wound complications attributable to the policy. It is felt, but not known, that the eventual percentage of recurrences would be considered satisfactory. The policy of early ambulation in the treatment of inguinal hernia was discontinued by the Surgeon-General in a directive dated July 13, 1943.

The remaining 1908 cases comprised a representative group of abdominal cases.

Unless there were specific contraindications, such as shock, extreme debility, severe generalized peritonitis or an insecure wound, all cases were mobilized on the first postoperative day. The procedure was generally well-liked and accepted by all classes of patients. From the general point of view it was obvious that the morale of these patients was excellent and the effect of this on the preoperative cases was to remove much of the dread and fear of surgery.

There was a notable absence of bladder and bowel inertia and the problem of nursing was greatly simplified. After three to four days the average patient was pretty well able to look after himself and even to wait on the more recently operated upon. We have no record of the number of minor wound complications. Major wound complications were notable only by their absence.

It is definite that there was but one eventration. This occurred in an obese individual with intractable hiccough. There are records of four postoperative herniae — one following hysterectomy, one after the closure of a colostomy; one following nephrectomy and one at the site of a marsupialized pancreatic cyst.

A few mild cases of superficial thrombophlebitis were seen, and most were attributed to the practice of using a foot vein for the intra-operative administration of fluids. There were no cases of femoral or iliac thrombophlebitis. Two patients died from pulmonary embolism. One of these occurred 67 days postoperatively in a malnourished individual who had a stormy convalescence after a posterior gastro-enterostomy for duodenal ulcer. There is some evidence that this was related to an infusion of amigen into a leg vein. The other occurred in a young veteran with an inoperable retroperitoneal tumor. He was ambulant on the first postoperative day and had a normal course until he suddenly died on the tenth postoperative day with the classic symptoms of embolism. An autopsy was refused.

In conclusion, our experience, as well as the cumulative recorded experience of many surgeons, testifies to the physiologic soundness of early postoperative ambulation. It is a proved procedure of great benefit to patients and is deserving of a much wider employment.

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DISCUSSION.—DR. BRADLEY L. COLEY, New York City: The subject of early rising after surgical operations has been of great interest to me, and I feel we should be grateful to Doctor Burch for having presented his views and his experience while he was Chief of the Surgical Service at Brooke General Hospital. I can say, without hesitation, that his conclusions as to the advantages of early ambulation were borne out by the experience of other surgeons in the Eighth Service Command, where it was my privilege to serve for nearly three years. I should like to take up just one phase of the subject; namely, the effect of early ambulation on reduction of the incidence of phlebothrombosis and pulmonary embolism.

In the autumn of 1944 we surveyed the large Station, Regional and General Hospitals in the Eighth Service Command and collected the cases which had accumulated up to that time. Thirty hospitals reported a total of 153 instances of phlebothrombosis, with 54 pulmonary embolisms and nine deaths. In none of these cases had the patient been an early riser. Later, I did learn of an appendix patient allowed up early who developed a nonfatal embolism on the 14th day after operation.

While it seems clear that ambulation will not eliminate this dreaded complication of surgery, it is our opinion that it should do much to reduce its frequency.

Doctor Burch spoke of the directive which prevented us from adopting early ambulation in hernia patients. For the past six months on Dr. Carl Burdick's service at the Hospital for Special Surgery, we have made it a rule to allow all our hernia patients out of bed on the day after the operation. These cases include large incisional, umbilical, recurrent inguinal and femoral herniae. When sufficient time has elapsed to permit us to draw conclusions we will report our experience. Suffice it to say, however, that the immediate results have been gratifying to us and to the patients. Were we not using nonabsorbable suture material throughout, we would not have the assurance that the early rising of these patients is an entirely safe procedure.

A word of caution is timely. The mere fact that the patient with an abdominal operation is allowed to leave his bed and walk about does not imply that his activities can be unrestricted. He must be cautioned as to what he can safely do and what he must avoid, lest he place undue strain on his as yet unhealed incision.

If early ambulation is practiced intelligently it seems that it is a sane, a safe and a beneficial method of postoperative management.

DR. HERMAN E. PEARSE, Rochester, N. Y.: About a year ago I had the privilege of visiting some hospitals in Texas with Colonel Burch, and at that time learned of his results. I was greatly impressed then, as I am now. The method was not unfamiliar, for some of you may remember that some time ago Doctor Morton advocated early ambulation in older patients. We must admit to a certain amount of mental lethargy in not adopting this for younger, healthier patients. The fear of wound disruption by early ambulation is a myth, handed down to us from the past. A wound may be disrupted by involuntary action such as coughing, sneezing, or vomiting or by pressure from distention. It is not disrupted by voluntary effort, for

a patient will not hurt himself. Any activity within the limits of comfort is safe. I am confident that venous complications begin soon after operation and that early ambulation alone will not be enough to prevent them. Early activity in bed must be added. In the first 24-hour period a patient is out of bed only a short time, so the percentage of time in bed, even with early ambulation, may permit venous stasis. If the patient is ventilated to shorten the period of unconsciousness from anesthesia, if he is not deeply narcotized, if he is turned in bed and has leg exercises at frequent intervals, then these, added to early ambulation will, I believe, eliminate many of the surgical complications we accept as inevitable to major abdominal surgery.

DR. JOHN C. BURCH, Nashville, Tenn. (closing): There are several practical points about the technic of early ambulation. Preoperatively, it is a good idea to explain the method and to instruct the patient to do three things on reacting; these are: (1) To take deep breaths even though it hurts; (2) to turn from side to side; and (3) to exercise the leg muscles frequently by flexing and extending the foot. In addition, the method of sitting a patient up in bed is demonstrated. The patient, lying on the side and with the feet dangling, is brought to the edge of the bed, then the backrest is gradually cranked up. When the patient overcomes the usual giddiness, the full sitting position can be assumed easily with only minimal discomfort. This should be done several times during the first postoperative day and the patient encouraged to get up later in the day. This is most easily done by using a footstool as a step-down. The pain is not severe and is about the same as in turning. Giddiness and weakness are almost universally noted, but are generally overcome by the fourth or fifth day when average patients can pretty well handle themselves.

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# THE PYRUVIC ACID METHOD IN DEEP CLINICAL BURNS*

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THE CRUX OF THE PROBLEM, both systemic and local, in the treatment of the severely burned patient, relates to the wound itself. In the treatment of the local area the objective is closure of the wound at the earliest moment compatible with success and with a minimum mortality rate. In the patient with an extensive deep burn this should be the objective of all treatment, beyond the early stages of impending or actual peripheral vascular failure. This concept we believe to be the compelling one from a practical standpoint.

The systemic consequences of the large deep burn are too well known to require recital, but it is pertinent here to note that beyond the first few days after injury the general condition of the patient is determined in large measure by one particular feature of the local area. The profound disturbances in the chemical sphere characteristic of this type of patient are reflections of the *open* condition of the wound. This is strikingly witnessed by the precipitous general improvement in the seriously burned patient when the wound is promptly closed. Clearly, the ultimate problem of the patient as a whole is most directly soluble on the basis of the local area. The solution is prompt *closure* of the wound.

The achievement of this objective in the patient with extensive deep burns poses formidable difficulties, however. The present report deals with one of these specifically, and indicates, in general, its bearing upon the others.

Split skin grafts including a proper thickness of the important derma are preferred for closure in large deep burns. Early skin grafting is a major penultimate goal, therefore, but it is not synonymous with closure of the wound. The chief cause of delay in the early grafting of these wounds is, in effect, the continued presence of the slough. This layer of dead tissue is slow

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to separate and is essentially powerless to combat infection; with it skin grafting is impossible, and contraction continues as long as the wound is open. It is regarded as of signal importance, therefore, to bring about the removal of the slough at the earliest moment. The advantage of this rapid removal is fully realized, however, only when the new surface of the wound is acceptable for immediate skin grafting, and when there is no significant damage to living tissue.

In a previous paper (Connor and Harvey,[1] 1944) we presented a brief summary of a method for the local treatment of deep burns based upon the results of experiments in animals. The central theme of the present report deals with the same method adapted for use in man, and the evidence is based upon clinical data.

Fundamental in these studies is the thesis that the hydrogen ion concentration is an important factor in the healing of the local area in deep burns. The results of preliminary experiments revealed that the separation of the slough can be exceedingly hastened if the *p*H on the surface of the wound is sufficiently lowered, with proper attention to other chemical factors. A large series of organic and inorganic acids were studied for their pertinent effect. Pyruvic acid was found to exhibit outstanding advantages within the recognized objectives of treatment.

## METHOD

The following data are descriptive of a general method for the use of pyruvic acid in the local treatment of clinical deep burns.

The stock solution of pyruvic acid is made by adding 7 cc. of pyruvic acid C.P. to one liter of distilled water. The *p*H of the resulting solution should be 1.9.

A content of from eight to ten per cent of cornstarch is desirable in the pyruvic acid starch paste. The exact amount of starch necessary varies somewhat with different commercial brands, but in final consistency the paste should be only semiliquid, permitting easy application. The preparation of the paste is the same whether a large or a small amount is made at one time. The desired volume of stock solution of pyruvic acid is separated into two portions, one (A) of about 20 per cent of the total volume and the other (B) of the remaining solution. Portion (A) is mixed without heating with a calculated amount of cornstarch (8–10 per cent), and thin cold starch paste obtained. Portion (B) is heated to just short of boiling. Portion (B) is then mixed with (A), the cold starch paste, and stirred. With total volumes greater than 400 cc. additional heating with constant stirring for about one minute may be necessary, in order to produce an homogeneous, relatively thick paste. This is then cooled by placing its container in an ice bath. The paste thickens somewhat with cooling.

(Example: If 500 cc. of stock solution of pyruvic acid at *p*H 1.9 is used, about 100 cc. of this is mixed with 50 grams of cornstarch, without heating. The remaining 400 cc. is heated almost to boiling, and the two portions are mixed, stirred, heated a little longer if necessary, and cooled.)

In the use of this method in the treatment of mixed burns certain general points are of great importance and deserve emphasis.

(1) The success of the method depends to a considerable degree upon the *maintenance* of a *thick* layer of active pyruvic acid paste in contact with the wound.

A relatively *large amount* of paste should be applied, to minimize neutralization by the wound fluids. The paste should be applied generously in a thick layer. This is

most readily done by placing the paste on a thin layer of gauze or on a sheet of appropriate size, which is then applied with the paste next to the burn. After application this inner dressing is covered with strips of vaselined gauze or some impermeable dressing so that it does not dry out. For example, in the treatment of a burn involving the entire lower leg, from knee to ankle, about 3,000 cc. of paste is advisable. An excess amount of paste can be used with safety, an inadequate amount is relatively ineffective.

The dressing should be such as to maintain this thick layer of paste in contact with the wound, and to prevent any conspicuous drying out of the paste. Under a properly applied dressing the paste should not dry out between dressings.

(2) Preliminary cleansing or débridement of the wound is unnecessary. In this connection two points deserve notation, the treatment of blisters and the cross-hatching of the slough, but neither of these can be properly classified as "débridement."

(3) Blisters may or may not be opened. In any instance in which the presence of the slough beneath the blister is suspected, and this occasionally occurs, the blister should be unroofed to expose the dead tissue. If this is not done, the treatment will be ineffective in this area.

(4) Separation of the slough by this method proceeds from the margin of the wound. It is therefore highly advisable in large wounds to incise the slough with a scalpel in order to create more "margins." This can be done without anesthesia. The incisions should be carried through the dead tissue in a linear manner.

(5) Areas of first-, second- and third-degree damage can be treated under the same dressing without conversion of the superficial into deep burns.

*First Dressing.*—The first dressing with the pyruvic acid paste may be performed at any time. In the severely burned patient, in danger of death from peripheral vascular failure, it would appear wise to delay this definitive treatment of the wound in favor of those measures useful in combating the so-called "shock." But the pyruvic acid dressing may be properly applied at once otherwise. In instances in which the local external plasma leakage is excessive, the first dressing may be relatively ineffectual from the point of view of separation of the slough, but this obtains only for a day or two.

Without preliminary cleansing or débridement the dead tissue is incised to provide greater margins, blisters are unroofed if necessary, and the pyruvic acid paste is applied generously in a thick layer directly to the wound. Paste of the proper consistency can be piled in place in many instances. The paste is covered with a thin retaining dressing of dry gauze, which, in turn, is thoroughly covered with large sheets of vaselined gauze or other impermeable dressing to prevent drying. The vaselined gauze has the advantage that, when spread out to include a portion of the adjacent unburned tissues, it helps to anchor the dressing in place and to seal off these edges of the dressing. This is an important feature of the dressing, for properly performed, it is completely adequate to prevent drying out of the paste. This dressing is then covered with a bulky gauze roll and anchored with elastic bandage for security. Splints are incorporated in the outer dressing if necessary, but the best insurance against deforming contractures is early closure of the wound with proper skin grafts.

The application of dressings of pyruvic acid paste to large burned areas on the extremities can be simplified by placing the burned area on a sterile towel, and applying the paste generously to the wound and on the towel; the paste-filled towel is then drawn around the extremity, anchored and sealed with large sheets of vaselined gauze. Such a method insures the covering of the wound with a thick layer of paste, and over it the outer dressing is easily and efficiently applied.

For the treatment of burned areas on the flat surfaces of the body, as the dorsum of the hand and the trunk, the paste is easily held in place within a dam of built-up gauze applied to the greased unburned skin at the margins of the wound. Within this dam of gauze the paste is placed in a thick layer, covered with dry gauze and sealed

with sheets of vaselined gauze. Such a dressing maintains the pyruvic acid in place without drying for several days.

Whenever possible in instances of burns of the extremities, the unburned distal portion of the extremity should be left exposed for inspection. A few preliminary vertical incisions through the slough are good insurance against compromise of the circulation locally from the tourniquet effect of the unyielding eschar.

*Pain* is irregular in occurrence after these dressings. It is reasonable to expect pain after the application of pyruvic acid directly on a denuded second-degree area, but this has not been invariably the case. The intensity and duration of the pain, when present, are also variable. Although several large burned areas of mixed degree have been successfully treated by this method without apparent pain, it would seem wise to administer codeine or morphine about 15 minutes before at least the first dressing. Various methods have been used for the incorporation of a local anesthetic agent into the pyruvic acid paste, but these have not been refined sufficiently to make them safe in the presence of large wounds.

*Subsequent Dressings.*—The *p*H of the pyruvic acid paste rises in the presence of the wound fluid, particularly when the external plasma leak is excessive (the first few days after burning) and when the slough has begun to separate. Dressings should be performed at intervals of two to three days, if possible.

When the previously placed dressing is removed the paste should not have dried out, and the entire inner dressing should fall away from the wound without pain. A thin layer of paste usually remains on the surface of the wound; this should be wiped away gently.

The conspicuous change at the first redressing is the *demarcation* of the areas of dead tissue, and this occurs whether the burn extends only into the depths of the derma or into the deeper layers. In fresh burns there may be little gross evidence of separation at this time; in older burns the edges of the slough may show obvious separation.

Whether or not débridement is combined with the use of pyruvic acid at redressings (see below for discussion) the new dressing is applied in a manner entirely similar to that used in the previous one, a generous application of paste being used.

At the second redressing in large third-degree burns beginning separation of the slough should be apparent. It is at this time that débridement according to a particular technic is of great value, for the demarcation of the slough in both the vertical and horizontal planes will be obvious.

In third-degree burns not involving tendons or thick fascia the wound should be ready for split grafting within a week or slightly longer. The new base of the wound should consist of well-vascularized early granulation tissue. If grafting must be delayed momentarily, the wound may be dressed with a small amount of the pyruvic acid paste.

*Deep Second-degree Burns.*—Areas in which the damage extends only into the depths of the derma, with preservation of deep epidermal islands but with a covering of slough, should receive the same treatment as deeper areas. When the cleavage plane is within the derma, an additional 48 hours may be required for complete separation of the dead tissue. When such separation has taken place, however, the wound should heal promptly, if sufficient epidermal islands are present. In such instances healing is often surprisingly rapid when the slough is speedily removed without clinical infection, even though the layer of dead tissue is relatively thick.

*"Débridement."*—The early demarcation of the slough and consequent definition of the proper cleavage plane with this treatment permits a valuable modification of the method. This consists in the use of "débridement" together with pyruvic acid at the time of the redressings. The term "débridement" is employed rather loosely in this connection since the maneuver is used merely to hasten, but not to complete at one sitting, the separation of the slough.





FIG. 2





FIG. 4





FIG. 6

PLATE I

FIGS. 1 and 2.—Case 1. A. C.: Separation of the slough in one piece through the development of a cleavage plane beneath it (see text).

FIGS. 3–6.—Case 2. J. K.: Severe electrical burn of arm and leg, to show rapid separation of the slough and clean granulating wound (see text).

Although separation of the slough proceeds with the use of the pyruvic acid paste alone, the process can be materially hastened with safety when the demarcated plane of cleavage is developed by sharp dissection for a few centimeters beyond the established limits of complete separation. This is true *even though the cleavage plane is within the derma,* and sufficient residual epidermal elements are present. The safety of this maneuver is dependent upon the fact that the proper plane of cleavage is sufficiently defined by demarcation of the slough to be obvious grossly, and that a zone of incomplete separation often lies among the areas of complete separation. For example, in a large deep burn at the end of four days of treatment the slough may have separated at the edges so that elevation of these margins reveals only vertical strands of dead connective tissue anchoring the slough to its base, with many large and small intervening areas of complete separation. When these anchoring strands of slough are divided, bleeding is absent and the cleavage plane is further developed, so that the subsequent application of pyruvic acid reaches the more remote areas under the residual slough. This extension of the line of cleavage, surgically, should properly extend inward only to the point where demarcation is entirely clear, if the destruction of residual epidermal elements and bleeding are to be avoided.

*Stronger Stock Solution.*—When there is no question of preservation of residual epidermal islands, the strength of the stock solution may be increased to 9 cc. of pyruvic acid per liter of distilled water, until the slough has separated.

When the slough includes dense tissue or tendons, separation is considerably hastened when débridement by the above technic is employed in addition to pyruvic acid.

## RESULTS

More than 30 cases have been treated in this manner, many of them with multiple wounds. The results have been similar to those previously described in the experiments in animals. The layer of dead tissue separates rapidly, and living islands of skin survive in those areas in which the full-thickness of the skin has not been destroyed in the burning. The deep wounds are then acceptable for immediate grafting, and in the more superficial wounds the islands of viable epidermis regenerate. All areas of the mixed clinical burn may thus be treated under the same dressing.

The manner of separation of the slough under these circumstances is of great significance. This is strikingly apparent in the experimental wound and is equally clear in the clinical cases. Separation appears to begin at the margin of the slough and to proceed centrally through the development of a plane of cleavage beneath the dead tissue. The slough separates in large sheets. It is clearly apparent that the slough itself is not digested. This is well-illustrated in the following case, and in Case 4:

CASE 1.—A. C., a white male, age 50, sustained deep burns of the thighs in attempted suicide, and was admitted to the hospital in critical condition from carbon monoxide poisoning. The wounds were treated with vaselined gauze and pressure dressings. After 20 days the slough had failed to separate and was firmly adherent in all areas, even at the margins. A dressing of pyruvic acid was first applied at this time. The proximal few centimeters of the wound on each thigh was left *untreated,* except for a minimal amount of paste which leaked onto this area. The remainder of the wound was completely covered with a thick layer of paste.

The dressing was changed three days later. The slough had separated markedly in many peripheral areas but was firmly attached proximally. Pyruvic acid paste was again applied in a thick layer.

*Six days after the initial treatment* by this method the slough had completely separated except for a thin proximal band (Fig. 1). The slough lay on the surface of the wound and could be lifted free, hinged proximally (Fig. 2). The separated layer of dead tissue itself was rubbery and intact in a single sheet on each wound. The granulating surface of the wound was clean and highly vascular, but there was no bleeding from it. At the margins of the wound there were several areas of viable deep derma. The surrounding skin was uninjured.

The granulating wound was successfully closed with split grafts. In the areas of exposed deep derma at the margin epidermal islands promptly regenerated, but in the remainder of the wound the damage was of third-degree.

This case illustrates particularly well the separation of the slough through the development of a cleavage plane beneath it. The slough itself was not digested. With this treatment it is clear that separation begins at the margin. In this case the margins of the wounds were relatively large compared to the area of the slough, and the slough was purposely not incised to create more margins. In circumferential deep burns of the extremities the margins of the wound may be exceedingly small (Case 4); under these circumstances there is a great advantage in a few linear incisions through the dead tissue in order to provide a relatively large "margin."

Preparation of the local area in the large deep burn for grafting within a period of even a month is often regarded as efficient treatment in clinical practice. With proper application of the pyruvic acid method the usual large deep thermal burn should be ready for successful grafting within a period of ten or 12 days, often in less time. Smaller burned areas should be prepared within a proportionately shorter period, approaching that previously noted in the experimental deep burn.

The surface of the wound is exceptionally vascular after separation of the slough by this method, but there is no bleeding. When the treatment is begun at an early date, and is intensive, this new surface of the wound may have the general appearance of pink subcutaneous tissue; histologically, it is early granulation tissue. The edges of the wound are sharp and clean.

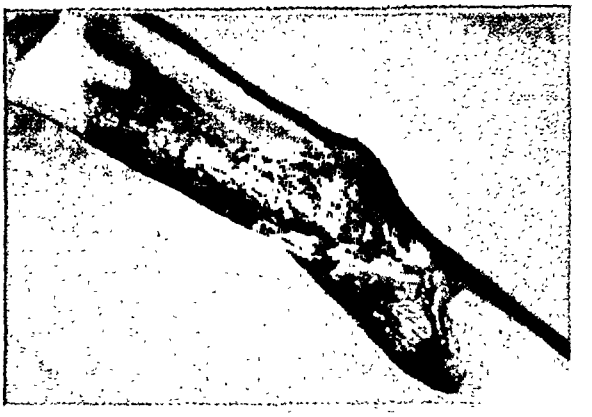
Severe electrical burns are commonly regarded as particularly destructive and troublesome. They would appear to be an adequate testing ground for the efficiency of a method of local treatment. Many of the features of the present method are shown in the following case:

CASE 2.—J. K., a white male, age 51, sustained severe electrical burns of the arm and legs from prolonged contact with a high tension wire. The wounds were treated initially in another hospital with a thin dressing of sulfonamide cream. This, and a dressing of vaselined gauze, were the only local treatment for two days.

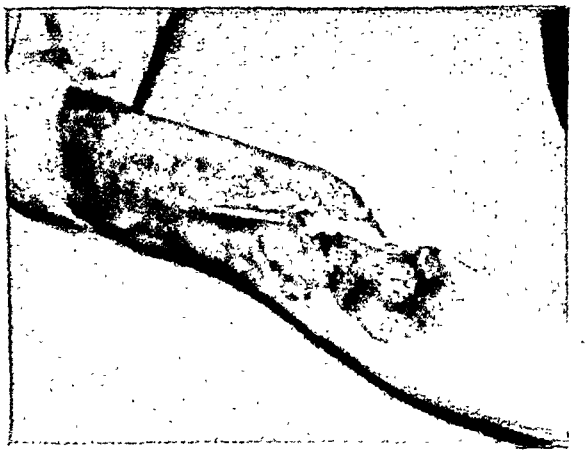
*Two days after burning,* and before the first dressing with pyruvic acid paste, the local areas revealed evidence of marked destruction (Figs. 3 and 4).

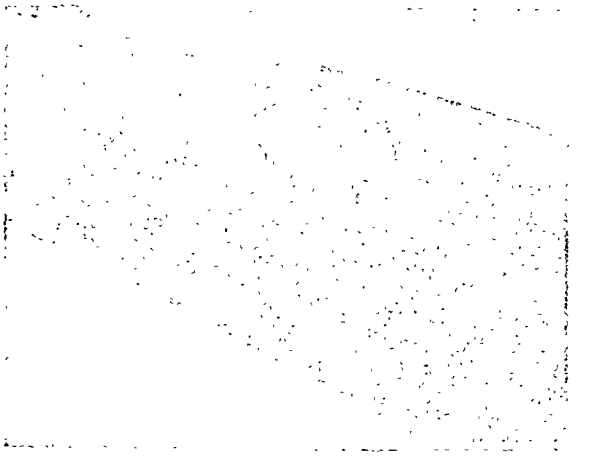
The soft tissues of the arm (Fig. 3) were completely divided down to, and exposing, the humerus just above the elbow. A wrist drop was present. This arm had supposedly hung sputtering over the high tension wire. When the divided muscles which filled this groove were separated, a charred mark about 2 cm. in diameter was viable in the humerus itself, and this bone was bare over two-thirds of its circumference for a distance of about 5 cm. The adjacent tissues upward and downward from this groove were the site of a rubbery, insensitive slough which was firmly





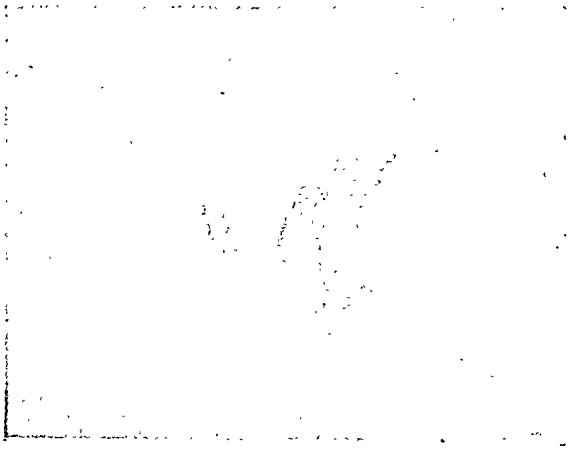
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PLATE II

FIGS. 7–9.—Case 2. J. K.: Severe electrical burn of arm and leg, to show rapid separation of the slough and clean granulating wound (see text).

FIGS. 10–12.—Case 3. E. E.: Deep second-degree burn, to show prompt separation of slough with preservation of viable epidermal islands (see text).

adherent. A large patch of gray similar tissue extended medially across the antecubital space.

A similarly destructive injury was present over the left thigh, popliteal space and lower leg (Fig. 4). Here, again, the soft tissues had been divided in the burning down through the muscle. The tibia was exposed just below the knee for a distance of about 2 cm. The remainder of the burned area was covered with a layer of rubbery gray tissue which was firmly adherent. A drop foot was present.

On the opposite thigh (right) was a smaller area of damage without actual division of tissue. This was covered also with a layer of adherent, insensitive slough.

In view of the nature of the burning agent (electricity) and the actual division of tissue under these circumstances it was suspected that the damage was even more extensive than it appeared to be.

The pyruvic acid treatment was started at this time, two days after burning. Edema had become marked in the unburned tissues distal to the burn. A linear incision was made in the unyielding slough over the arm and over the popliteal space without anesthesia. All of the wounds were treated simultaneously, and a thick layer of pyruvic acid paste was applied.

The dressings were changed at the usual intervals of a few days. Large areas of slough promptly separated in sheets, some of which are shown in Figures 5 and 6. The slough of skin and subcutaneous tissue which came away from the knee and thigh was more than 0.5 cm. in thickness in several areas (Fig. 5). In addition, sections of muscle at least 6 cm. in thickness (Fig. 6) separated in one piece from the walls of the original grooves in the arm and leg. The slough itself was not digested, and separation had taken place through the development of a cleavage plane beneath it.

*Thirteen days after the first pyruvic acid dressing* all of the wounds were free of slough and in excellent condition (Figs. 7, 8 and 9). The vascularity of the exposed tissues characteristic of this treatment was marked, but there was no bleeding from them. In the right arm (Fig. 7) the humerus was exposed for several centimeters. The bone here appeared a dead grayish-white in color and presented the previously noted blackened area in it. The edges of the wound were sharp and clean. In the left leg (Figs. 8 and 9) the wound was essentially similar to that in the arm. Tendon and fascia were exposed around the knee, but these tissues appeared to be viable. The tibia was exposed as already noted.

The soft tissue wounds were covered with thick split grafts which survived for closure of the defect in these tissues.

The utility of this method of treatment would be seriously reduced if with its use residual epidermal islands within the wound were necessarily destroyed. This is not the case, however, for in those burns in which the serious damage extends only into the derma, but with preservation of residual epidermal islands, separation of the slough proceeds so as to permit regeneration of these islands. The cleavage plane develops within the derma at the appropriate depth.

This emphasizes an important feature of the method. In the standardization of the procedure for practical application the concentration of pyruvic acid was chosen with this consideration. When there is no need for preservation of these deep epidermal islands a stronger solution of pyruvic acid may be used, with even more rapid separation of the slough. The usual clinical deep burn is a mixed one, however, with at least small areas of more superficial damage. In repeated instances in the present series of cases numerous viable epidermal islands have been present after separation of a thick slough

by this method. The method was standardized with a view to the preservation of these deeper epidermal islands. All areas of the mixed clinical burn may thus be treated under the same dressing without fear of converting the superficial injury into a deep one.

A conspicuous feature of this method is the early *demarcation* of the slough in questionable areas. In fresh burns it is often difficult to determine with accuracy in the beginning the extent of the layer of dead tissue.

The following case illustrates the separation of the slough in a wound in which deep epidermal islands were viable. Although the area in question is small, this case was chosen as particularly suited to illustrate the point. The small local area was intensively treated from the beginning, and when the slough had separated, the exposed surface of deep derma was further treated with the same pyruvic acid paste. This additional treatment is not recommended, as other agents are better adapted for use once the local problem involves only epithelization from islands within the wound.

CASE 3.—E. E., a white female, age 26, sustained a burn of the upper and lower arm when her sweater caught on fire. The burning was of short duration. She came to the hospital within a half hour after injury.

The entire arm was burned. Most of the local area appeared to be only superficially injured, however, with many intact and collapsed blisters. There was one grayish area on the inner aspect of the upper arm near the elbow (Fig. 10), suggesting somewhat deeper damage.

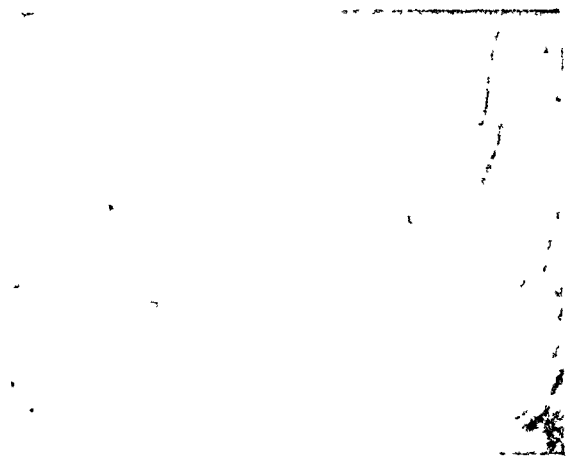
The entire burned area on the arm was dressed with a thick layer of pyruvic acid paste. The patient reported (on questioning) a slight local twinging sensation for about five minutes, but refused medication.

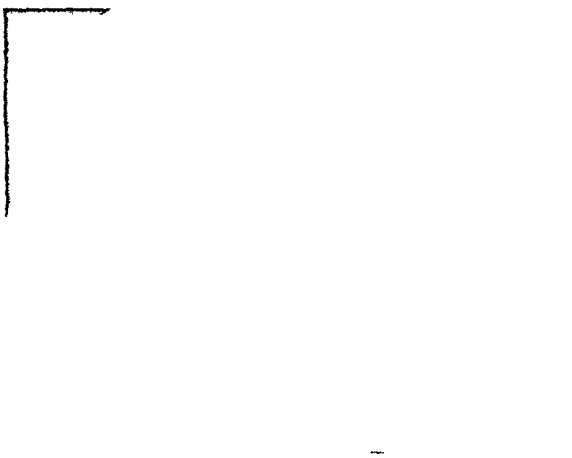
*Two days later* there was conspicuous demarcation of the slough on the grayish area previously noted (Fig. 11), but there was no gross evidence of separation. The adjacent blistered area appeared undamaged. Pyruvic acid paste was again applied, and medication for pain was not required.

*Three days later* the slough had markedly loosened but had not completely separated. When its edge was lifted, however, it was apparent that only a few soft dermal strands held it in place. The layer of dead tissue was peeled away at this time, like wet paper from glass. There was a slight hang at only one point near the center. The separated slough was intact (Fig. 12) and showed no evidence of digestion. The surface of the wound exposed after separation of the slough appeared to contain deep dermal tissue (Fig. 13) and was clinically clean.

This wound, free of slough, was treated for an additional five days with a thin layer of pyruvic acid paste. Numerous epidermal islands in the base of the wound regenerated in spite of this treatment, and the entire wound was completely epithelized one week later. The patient failed to return for photography but was finally induced to do so, one month after burning (Fig. 14).

The impression that superficial burns (without a significant covering of dead tissue) form an adequate testing ground for the efficiency of method for the local treatment of burns in general is a mistaken one, and has led to waves of enthusiasm for procedures which fail to prove their advantage in the presence of slough. We wish to note, therefore, that Case 3 has been cited only for the specific purpose of illustrating the safety of the pyruvic acid method in this type of injury.









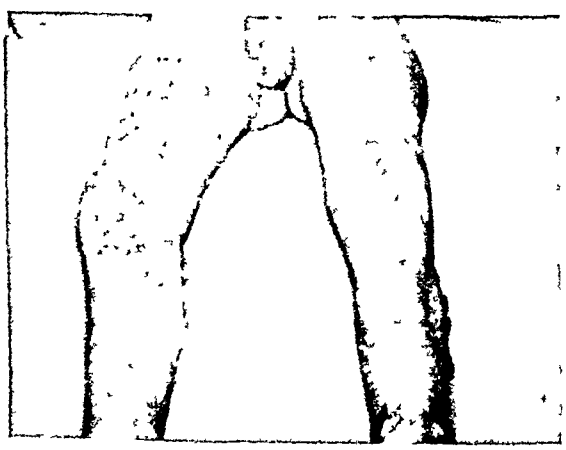




PLATE III

FIGS. 13 and 14.—Case 3 E. E . Deep second degree burn, to show prompt separation of slough with preservation of viable epidermal islands (see text).

FIGS. 15–18.—Case 4. J. V.: Severe deep burn by fire, to show rapid separation of slough in sheets, clean granulating wound acceptable for prompt closure with split grafts, immediate and late results of grafting (see text).

The full advantage of the rapid removal of the slough is realized only when the wound is acceptable for immediate skin grafting and is promptly closed, even though it is extensive. When the entire large deep burn is rapidly prepared for grafting, the gain is only a relative one unless the open wound is promptly converted into an essentially closed one. As has already been noted, this concept we believe to be the cogent one from a practical standpoint.

The clean vascular surface exposed in deep burns after separation of the slough by this method is admirably suited to support a covering of living skin, regardless of the presence of bacteria as indicated by culture. This is true even in the deep burn which is clinically infected when the pyruvic acid treatment is begun (see Case W. T., Connor and Harvey,[1] 1944). It is probable that few bacteria multiply and that many will not survive at the concentration of hydrogen ions present in the pyruvic acid paste. The more important factor in the survival of the skin grafts is believed to be the highly vascular clean surface of the wound, since bacteria are regularly obtained upon culture of this area.

It is understood that the rapid closure of the extensive deep burn free of slough poses serious difficulties. The various ramifications of this aspect of the problem are widespread, but it is pertinent to note here that the pyruvic acid method attains real significance in direct proportion to the speed with which the prepared open wound is converted into an essentially closed one.

The following case illustrates the relationship of the pyruvic acid method to the general problem in severe deep burns:

CASE 4.—J. V., a white child, age eight, was admitted to the hospital a half hour after having sustained a severe burn of both entire lower legs when his clothes caught on fire. There was some delay in extinguishing the fire since he had oil on his trousers. His left stocking was rolled down around the ankle and was also oil-soaked.

At the time of admission to the hospital both lower extremities were circumferentially burned. A linear incision was made in the unyielding charred skin to avoid constriction. A conspicuous ring of gray tissue was present around the left ankle at the level of the malleoli, this being notable in view of later developments. The greater part of both lower extremities appeared seriously damaged.

Intensive measures to combat peripheral vascular failure were instituted, and a pressure dressing was applied over vaselined gauze without preliminary cleansing.

*Three days later* the patient's general condition was satisfactory and the first dressing of pyruvic acid was applied, 6,600 cc. of paste being used for both lower extremities. The burned areas were little changed (Fig. 15) and were incised with a scalpel, linear and transverse incisions several centimeters apart being made to create more margins before the dressing was applied. The wound was not cleansed or débrided.

*Two days later* the slough had begun to separate. A dressing of pyruvic acid paste was again applied to both lower extremities.

*Three days later* (eight days after admission, five days after first dressing with pyruvic acid paste) much of the slough was hanging loose or had completely separated in a large sheet, and most of the remainder of the slough was held in place only by soft strands (Fig. 16). It was clear that a cleavage plane had developed beneath the slough which was still in place, and that the separated slough was without evidence

of digestion on its surface. The separated slough, which hung loose in sheets, was cut free from the incompletely separated dead tissue. Pyruvic acid paste was again applied.

*Two days later* (ten days after admission, seven days after the initial pyruvic acid dressing) the wound was free of slough and acceptable for grafting. The patient developed serum sickness (tetanus antitoxin administered on admission) which lasted for only a few days. There was considerable difficulty in securing compatible blood donors, the patient being *Rh-negative.* Extensive grafting was planned for the first operation, and intensive efforts were made to bring the patient's general condition to a high level to permit this. An exceptionally high protein diet was administered and the daily urinary output was maintained at about 2,000 cc.

*Five days later* (12 days after initial pyruvic acid dressing) sufficient compatible *Rh-negative* blood was available, and the wounds were in excellent condition. There were several striking features of the burned areas at this time. The surface of the wound was clean and highly vascular without bleeding (Fig. 17). The deepest damage was at the ankle on the left side. Both malleoli were exposed over an area of more than a centimeter in diameter, the joint space was widely open medially and laterally; the Achilles tendon, the peroneal and extensor tendons at the ankle were also exposed. These tendons appeared to be in good condition otherwise.

On this day the wound was extensively covered with split grafts, these being secured from both buttocks, the lower back on each side, both shoulders, both sides of the anterior abdominal wall and the anterior chest. About 200 square inches of skin was grafted at this one operation. Donors for homografts had been kept in readiness but were not used since the patient withstood this extensive procedure well. The granulating areas over the knees and popliteal spaces, and the exposed tendons were covered first, since these were of the greatest importance from a functional standpoint; the exposed tendons were grafted directly. All the available skin grafts were used without accurate patching, since skin was at a premium for complete coverage of the large granulating areas.

The grafts took well in all areas, including those over the Achilles tendon and extensor tendons. Intensive general treatment was continued to permit successive operations for closure of the wound as soon as possible.

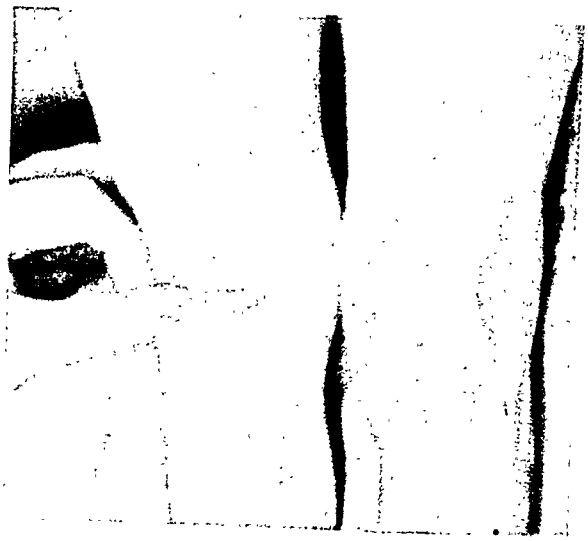
*Seven days after the original skin grafting,* additional split grafts were taken from the skin in the axillae and over the lateral aspect of the chest and buttock on each side as well as from part of one of the *previous donor sites,* permitting further closure of the wound. Again, effort was made to conserve skin and small areas were left between the grafts in some places. The previous grafts had taken around the malleoli which had been exposed, but this bone was now covered with granulation tissue, which was covered with small grafts at this operation. The patient tolerated this procedure well.

*Five days later* (12 days after the first grafting), much of the wound was covered with living split grafts with an adequate dermal pad (Fig. 18). Greatest attention had been given to the knees, and the grafts here were placed close together. Patchy areas of granulation tissue were apparent where the grafts otherwise had been spread for greatest coverage but without too much regard for small areas between them.

In addition to these small areas there remained one large area on the posterior aspect of the upper thigh on each side and one on the lower leg, yet to be grafted. Most of these were covered on this day with sheets of skin obtained from *three of the original donor sites which had now healed.* The original grafts taken from these areas were used to cover the knees and contained about one-half of the derma.

*Thirty days* after the first pyruvic acid dressing (33 days after admission) the wound was essentially closed (Fig. 19). There remained only a few scattered granulating areas in between the grafts which had been placed for greatest coverage without accurate patching. Three small areas were closed with bits of split grafts in order







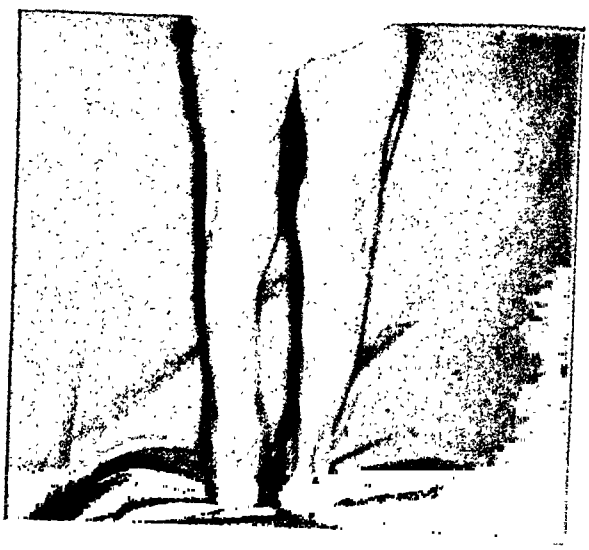


PLATE IV

FIGS. 19–22.—Case 4. J. V.: Severe deep burn by fire, to show rapid separation of slough in sheets, clean granulating wound acceptable for prompt closure with split grafts, immediate and late results of grafting (see text).

to improve the ultimate functional result, although most of them would probably have epithelized rapidly.

Fifteen months after the original injury the local areas were all in excellent condition (Figs. 20, 21 and 22). There were no contractures, the transplanted skin was durable and freely movable (Fig. 20), especially over the important area of the knees. There was no palpable deep scarring except over the left ankle where, it will be recalled, the joint space had been widely open and many of the supporting ligaments destroyed. This joint had become dislocated and there had developed evidence of a local epiphysitis. The functional result was otherwise excellent.

## SUMMARY

The results in clinical cases of deep burns treated by the pyruvic acid method support those obtained with similar treatment of experimental burns in animals. The slough separates rapidly without significant damage to living tissue, and the wound is immediately acceptable for extensive skin grafting regardless of the presence of bacteria as indicated by culture. The ultimate objective of treatment in deep burns, namely, the early closure of the wound, can thus be speedily achieved.

The authors wish to express their appreciation to Dr. Philip B. Cowles of the Department of Immunology, Yale University, for his invaluable assistance in this study.

Acknowledgment is due to Miss Mildred Konick for the photography.

## REFERENCE

[1] Connor, G. J., and Harvey, S. C.: The Healing of Deep Thermal Burns: A Preliminary Report. ANNALS OF SURGERY, 120, 362–366, 1944.

DISCUSSION.—DR. JOHN STAIGE DAVIS, Baltimore, Md.: I had not intended to say anything tonight, but I cannot resist speaking about this last paper. The method has apparently solved the problem of disposing of deep burn sloughs, which is something we have been struggling with for years, and to which we have never previously had a satisfactory answer. The results shown are remarkable, and I think pyruvic acid is going to make a great difference hereafter in the treatment of burns. I congratulate Doctors Harvey and Connor on this splendid piece of work.

DR. OLIVER COPE, Boston, Mass.: All of us who have had the privilege of going to New Haven and seeing some of Doctor Connor's patients have been much impressed by the extraordinary change created by pyruvic acid paste. I have reservations regarding the exact rôle of the *p*H of the paste. There are properties other than the *p*H which may help along the way. Doctor Connor has not told us all of his tricks; he is adept at making epithelium sprout by changing from pyruvic to succinic acids.

Doctor Lund's paper, and the work his group has been doing has been of enormous interest to other workers in government research projects in this field. Vitamin C is interwoven with the alarm reaction and it and other vitamins may be involved in the reaction of the patient to infection. It has been of great interest and help to us to have seen their work.

In the absence of Doctor Moore, I would like to allude to our work. The methods which Doctor Moore has developed using radioactive isotopes are magnificent tools but, after all, the value of tools is the result and knowledge obtained with them. Doctor Moore has been able to tell us a lot, but we do not pretend to know all the answers regarding the massive red cell destruction in deeply and extensively burned patients.

DR. C. C. LUND, Boston, Mass.: I want to add my congratulations to Doctors Harvey and Connor. I admit I have been doubtful for a long time over the reports of the chemical débridement of burns, but I am now very thoroughly convinced, and feel I have been a little slow. I have not had any practical experience on the subject to bring to you. Of course, when it comes to deciding between chemical débridement and surgical débridement, both are advances, and both may find a permanent place in surgery, but nobody has yet reported on the comparative use of both methods in the same clinic. Doctor Cope's paper concerns a study of anemia by technics that our group has not used. However, anyone handling burns must be faced with the very serious problem of anemia. Formerly, it was generally believed that sufficient transfusions to keep the patient's hemogoblin in the neighborhood of 70 per cent was adequate treatment. Our patients have been much better when we have maintained the hemoglobin above 90 per cent.

DR. SAMUEL C. HARVEY, New Haven, Conn.: I would be regretful if this demonstration had deflected attention away from the work of Doctor Cope and Doctor Lund. There remains to be learned a great deal from these two papers, because we still will have, under the most favorable circumstances, suppurative wounds and the problems of metabolic deficiencies and anemia.

Doctor Connor deserves the entire credit for this work. It has been accomplished only by his most painstaking care of these patients. The details have not been given because of lack of time, nor has it been possible to consider the many other patients. These two cases were selected because they demonstrated instances which usually give rise to serious problems. I hope other clinics will feel inclined to try this procedure. A criticism has been made that it takes too much time. It does take a lot of time, but if one considers the length of time it takes to care for patients who otherwise remain in the hospital for many months, I think the credit is in favor of this more concentrated type of treatment.

DR. GERVASE J. CONNOR, New Haven, Conn. (closing): We wish to thank you for your kind remarks, and to Doctor Cope and Doctor Lund I may say that the respect is mutual. There is one word I should like to add. We may have left partly the wrong impression, since the pyruvic acid method has received the major emphasis in this discussion.

The proper objective in the treatment of large, deep burns is prompt closure of the wound. The pyruvic acid method becomes merely an improved means to a relatively unimproved end unless the prepared wound is promptly closed. The general condition of the patient is determined, in large measure, by the *open* condition of the wound. The problem of the patient, as a whole, is most directly soluble on the basis of this one fact. The solution is prompt closure of the wound.

# THE ANEMIA OF THERMAL BURNS*

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ANEMIA has become acknowledged as a common complication of any extensively and deeply burned patient who survives the period of burn shock. The anemia is progressive and is accompanied by debility. It may be so severe that the wounds will not heal unless massive transfusions of whole blood are administered.

The magnitude of the problem of anemia following severe burns is illustrated by the number of transfusions given to four patients before healing was achieved (Table I). These patients were treated in 1943, before the present study was initiated, and, indeed, served as a stimulus for the study. Two of the four patients (Cases 41 and 131)† entered this hospital 8 and 20 months, respectively, after injury, with extensive unhealed granulating wounds of the legs. Both patients were anemic, hypoproteinemic and emaciated. The other two (Cases 13 and 116) entered immediately following their injuries but were unwittingly allowed to become anemic and malnourished before red cell transfusions were started. None of these four patients was treated by expeditious closure of their full-thickness wounds. The necrotic slough was allowed to separate spontaneously, exposing open infected wounds. All were treated with sulfonamides and without penicillin. Numerous skin grafts elsewhere had been unsuccessful in the first two patients. Successful grafting in all was achieved only late after the injury, when the anemia and malnutrition had been partially relieved. The amounts of whole blood given these patients were minimal, certainly not optimal, since all four patients left the hospital with residual anemia and hypoproteinemia.

The origin of the anemia of burns was ascribed, in 1942, by Altemeier and Carter[1] to external loss of blood from the infected granulations. More recently, the frequency with which gross hemolysis and massive hemoglobinuria have

* The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Harvard University.

This work was also aided by a grant from the Ciba Pharmaceutical Products, Inc., Summit, N. J.

Read before the American Surgical Association, April 2-4, 1946, Hot Springs, Virginia.

† The same case numbers are used in all articles on burn patients studied at this hospital under contract with the Committee on Medical Research. Numbers 1 through 39 refer to the Cocoanut Grove fire cases, numbers 40 through 96 to cases studied before the Cocoanut Grove fire, and numbers 97 through 278 to cases studied since the Cocoanut Grove fire.

been encountered in the hours immediately following injury has called attention to an early destruction of red blood cells, allegedly due to the heat itself. Shen, Ham, and Fleming[2] have disclosed an early increased fragility of the red blood corpuscles. The Burns Unit in England, under Colebrook,[3] has extended this observation to find that by 18 hours all the fragile cells have disappeared from the circulation, leaving only the stable cells or those with decreased fragility.

In addition to the observed losses of red cells by hemorrhage from the wound surface and by hemolysis, other causes of a decrease in circulating red cell mass might be postulated. The administration of large volumes of plasma in the therapy of burn shock could theoretically give rise to destruction of cells if the plasma pools contained an excess of anti-A or anti-B agglutinins. Red cells may be destroyed at the inflammatory barrier of the infected wounds; Menkin[4] has shown a deposition of iron in this area. Wintrobe and his coworkers[5] have suggested that such a deposition may be the reason for deviation of iron from the bone marrow. They have observed hypoferremia associated with an anemia

TABLE I

THE PROBLEM—1943

TRANSFUSIONS GIVEN TO FOUR PATIENTS WHO WERE DISCHARGED WITH HEALED WOUNDS BUT WITH RESIDUAL ANEMIA

| Case Number | Extent Full-thickness Burn | Whole Blood Transfusions | Duration of Hospitalization |
|---|---|---|---|
| 41 | 20% | 4,500 cc. | 5 months* |
| 131 | 15% | 6,500 cc. | 8 months† |
| 13 | 28% | 12,500 cc. | 4 months |
| 116 | 12% | 2,500 cc. | 6 months |

* Burned 8 months prior to admission to this hospital.
† Burned 20 months prior to admission to this hospital.

refractory to iron therapy in patients with acute and chronic infection. It is also possible that toxins of infectious origin might suppress the regenerative activity of the bone marrow by means other than iron deviation.

These observed and postulated causes of anemia in the burned patient should all create a true anemia, or decrease in circulating red cell mass, which should be differentiated from the false anemia due to an increase in plasma volume resulting in red blood cell dilution. Such a false anemia has been shown to follow soon after the initial period of hemoconcentration. Studies of the redistribution of fluid within the extracellular space at this hospital,[6] and elsewhere,[7] have shown that once the interstitial or extravascular compartment of the extracellular space has been stretched to the maximum such an enlargement of the plasma volume may occur. This enlargement may be produced either by continued fluid therapy in excess of renal output or by beginning mobilization of fluid from the overdistended interstitial space. Clinically, such a fluid shift is recognizable as subsidence of edema which usually starts about 48 hours after the injury; if the wounds are extensive, blood dilution may persist for several days in spite of a large renal output.

The stubborn and disabling character of the anemia has prompted this investigation. We have strived to determine: first, the significance of the observed and postulated causes of the burn anemia; second, how far the customary methods of measuring an anemia suffice for the guidance of therapy and to what extent newer methods of blood volume determinations must be introduced as a clinical routine; and, finally, to record the relative expense in terms of red cells required under different modes of therapy. The expense of treating an established anemia has already been observed (Table I).

## METHODS

Studies of the peripheral blood alone may provide an approximation of the extent of an anemia. However, if whole blood is continually lost and dehydration is present, so that refilling of the plasma volume from the extracellular fluid is abnormally slow, hematocrit, hemoglobin, or red cell counts in the normal range may theoretically coexist with striking reductions in the circulating red cell mass. For this reason, as well as a desire to quantitate the loss, one must go beyond a description of the peripheral findings and measure the circulating red cell mass and the changes in this red cell mass after the burn.

Of the methods available to study the red cell mass, the simplest is a measurement of the dye plasma volume and a calculation of the red cell mass from the hematocrit. This method suffers from some systematic error traceable to the fact that the large vessel hematocrit is somewhat larger (about 10 to 15 per cent) than the whole body hematocrit.[8] However, this fault is not insurmountable if the same method is used for serial determinations and there are no acute changes in body fluid metabolism which alter the relationship between the whole body hematocrit and the peripheral hematocrit during the course of the study. The method is also affected by widespread alterations in capillary permeability and presence of other pigments in the serum.

A method which measures the red cell mass directly would be preferred and we have used a measurement of the patient's red cell mass by the injection of red cells containing radioactive iron and a quantitation of the dilution of these injected cells using physical measurements of the radioactivity.*[9,10]

In brief, this technic involves the preparation of radioactive red cells in a donor by the injection of the five-year half-life isotope of iron (as ferric ammonium citrate), over a period of two or three weeks. At the end of this time the activity of the donor may be determined and when it is sufficient to allow measurement of his cells diluted in the patient's cells, the build-up is ceased. At a time when the red cell mass of a patient is to be measured, the radioactive donor is bled of 100 to 500 cc. of blood into citrate and this amount is injected into the patient after careful measurement of the hematocrit of the injected blood. The radioactivity per cubic centimeter of cells in the donor blood, and

* In expressing the results in the figures the red cell volume as measured by calculation from the dye plasma volume is indicated as RV; the red cell volume as measured directly with radioactive cells is indicated as R*V.

in the patient's blood after an hour are then determined. By the extent of the radioactivity dilution the cell volume of the recipient is calculated. The activity measurements are made on a Geiger counter, after digestion of the red cells to ferric hydroxide and electroplating this iron onto a copper planchette.

The application of this method to such a problem as this allows one to carry out two other types of observations. The first has to do with the relative survival

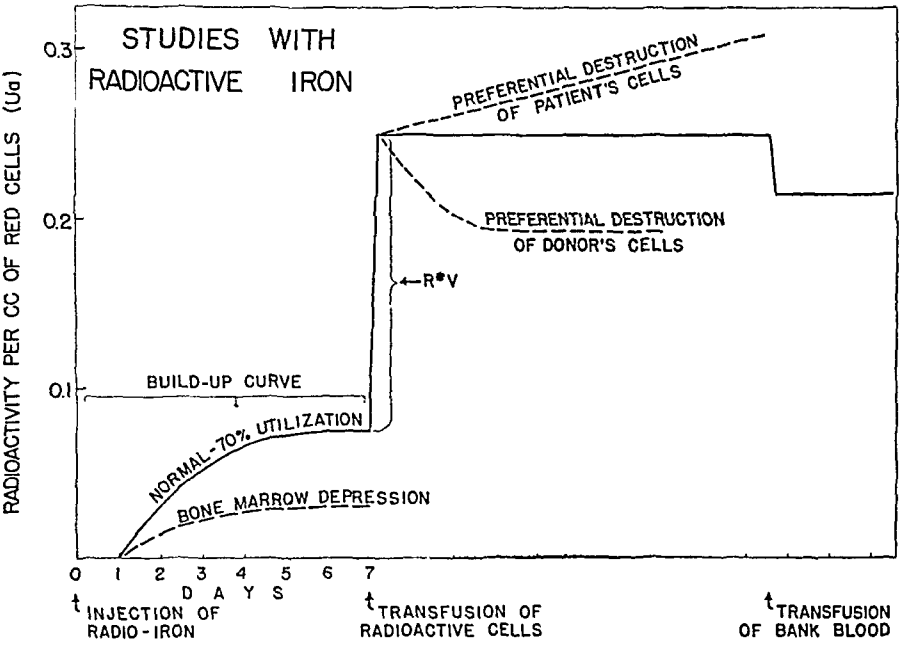



CHART 1.—Diagram demonstrating uses made of the radioactive isotopes of iron; the isotope $Fe^{55}$ (five-year half-life) was employed.

*Utilization of Radioiron:* An injection of iron as ferric ammonium citrate given at zero-day results in a gradual appearance of the iron in the peripheral erythrocytes as shown in the solid line of "Normal—70% Utilization". An example of depression of this utilization is shown by the dotted line.

*Measurement of Red Cell Mass:* A transfusion of whole blood from a donor in whom erythrocyte hemoglobin has been synthesized from radioactive iron by multiple build-up injections, results in a sudden rise, the height of which is directly proportional to the red cell mass (R*V), and from this rise the R*V may be calculated.

*Subsequent Fate of Cells:* Following such a transfusion the concentration of radioactivity in the peripheral blood remains constant under normal conditions (solid line). Destruction of the donor's cells due to poor preservation or incompatability results in a drop in activity (lower dotted line). Active hematopoiesis also results in a fall of activity as ordinary iron is built into new cells.

If the patient's own cells are preferentially destroyed, a relative rise in activity (upper dotted line) would result.

Transfusions of ordinary bank blood result in a sharp fall in activity.

It should be emphasized that the radiation from this isotope of iron is a low energy *beta* ray which produces no known deleterious biologic effects in the small quantities used.

of the donor cells in the patient or the survival of the patient's own cells in his circulating blood. After a patient has received a radioactive transfusion, the radioactivity of his circulating cells will remain constant for long periods of time unless his cells and the donor cells are being destroyed in a differential fashion. For instance, if the patient is transfused with donor cells which have

been inadequately preserved or which are incompatible with the recipient, these cells will rapidly be destroyed and over a period of two or three days much of the radioactivity will disappear from the circulating blood as the radioiron is either excreted or stored again in the marrow for resynthesis. If the donor's cells are healthy, well-preserved erythrocytes, and the patient carries cells in his own blood which are either fragile or are being selectively destroyed at a rapid rate, then the specific radioactivity in the patient's circulating blood should gradually rise, as the patient's inactive cells are destroyed, and the donor's active

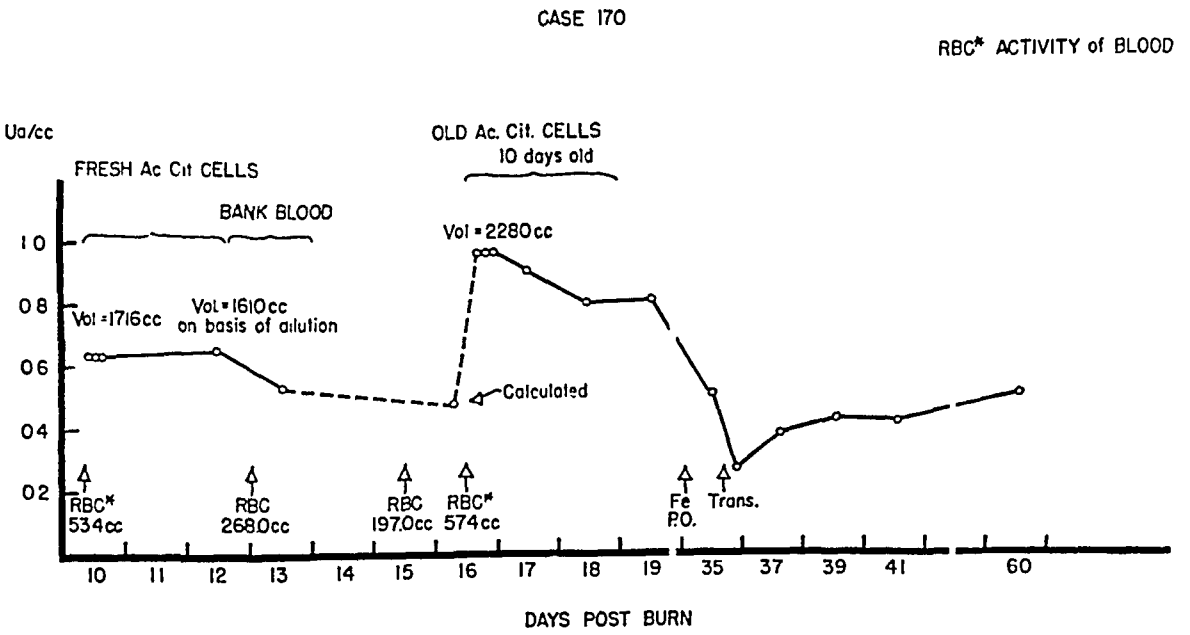



CHART 2.—Case 170: Radioactivity in peripheral blood in a patient with predominantly superficial burns, demonstrating dilution and preferential cell destruction phenomena of the radioactive iron technic diagrammatically represented in Chart 1.

On the tenth post-burn day the patient received 53.4 cc. of fresh, well-preserved radioactive cells yielding a calculated red cell mass (R*V) of 1,716 cc. (All figures in the chart are in cubic centimeters of cells.) On the 13th and 15th days transfusions of bank blood were given totalling 518 cc. of cells. On the 16th day a second radioactive transfusion was given increasing the concentration of cells containing radioactive iron in the peripheral blood. The second calculation of the red cell mass gave 2,280 cc., which figure indicates quantitative retention of the 518 cc. of cells given between the two measurements.

The second radioactive transfusion consisted of blood which had been poorly preserved (temperature inadequately controlled) and the fall in activity thereafter resulted from partial destruction of these fragile cells. Between the 19th and 35th day the patient's own marrow activity under iron therapy plus transfusions of bank blood resulted in a further fall, after which activity is essentially constant up to the 60th day.

cells remain viable. Therefore, over a period of days or weeks after the burn, determinations of the activity in a transfused patient permit one to draw conclusions as to whether or not the patient's own cells, which had been in the patient at the time of the trauma, are being selectively destroyed.

A second application of this technic involves a study of the build-up curves. If a normal individual is given a single intravenous dose of radioactive iron as ferric ammonium citrate, this iron will not appear in the circulating erythrocytes for about 24 hours as it is first taken up in the blood-forming organs and only slowly synthesized into hemoglobin. After this initial latent period the radio-

active iron begins to appear in the peripheral blood as erythrocyte hemoglobin at a characteristic rate and in a characteristic amount which may be described as an exponential rise in activity with a half-period of about three days and a final utilization of about 70 per cent of the injected radioactive iron. If, however, the patient is suffering from some disorder in which red cell formation is depressed, the appearance of this radioactive iron may either be slowed or its final utilization may be abnormally low. Conceivably, there may be situations in which bone marrow activity is increased and the build-up curve, therefore, either hastened or raised. We have not observed such patients, although we

TABLE II

Case 196
Male, Age 51, Weight 80 Kg.
Extent of Burn: 15 per cent total, 1 per cent third degree

RED CELL VOLUMES AND TRANSFUSIONS

| Day Post-Burn | Red Cell Mass: Dye Method Cc. Cells | Red Cell Mass: Radioactive Method Cc. Cells | Transfusions Cc. Cells |
|---|---|---|---|
| 0 | 2650 | | |
| 3 | | 2220 | 120 |
| 4 | | 2470 | 97 |
| 9 | 3250 | 2350 | 114 |

PERIPHERAL BLOOD EXAMINATIONS

| Day Post-Burn | R.B.C. Millions | Hemoglobin Gm./100 Cc. | Hematocrit % Cells | Reticulocytes % |
|---|---|---|---|---|
| 0 | 4.44 | 18.5 | 44 | |
| 1 | | | 48 | |
| 2 | | | 47 | |
| 3 | | | 42 | 0.3 |
| 4 | | | | 0.2 |
| 6 | 5.40 | 14.0 | | 0.3 |
| 8 | 4.10 | | | 0.4 |
| 9 | 4.39 | | 42 | 0.4 |
| 11 | 5.25 | | | 1.0 |
| 14 | 4.58 | | | 0.8 |
| 16 | 4.15 | | | 1.0 |

have not applied this technic to patients with such disorders as pernicious anemia in remission or true iron deficiency anemia under treatment. In Chart 1 some of the phenomena observable with radioiron are shown diagrammatically. In Chart 2 an example of such studies in a patient with a circumscribed burn is shown.

Operative blood loss has been computed from the concentration of acid hematin or of the radioactivity in the washings of sponges and drapes. The customary examinations of the circulating blood including reticulocyte counts have been carried out.

The end-products of red cell destruction have been measured in urine and feces because of our interest in the question of whether or not there was any correlation between the amounts excreted and the apparent destruction of red

cells in the blood. Both quantitative urobilinogen determinations[11] and the benzidine test have been carried out on urine and feces. On a few patients the hemoglobin concentration in the serum has been determined in the hours immediately following entry and the blood bilirubin concentration has been followed.

## RESULTS

Data have been obtained from the study of four patients with predominantly second degree burns, and 13 patients with deep burns of considerable magnitude.

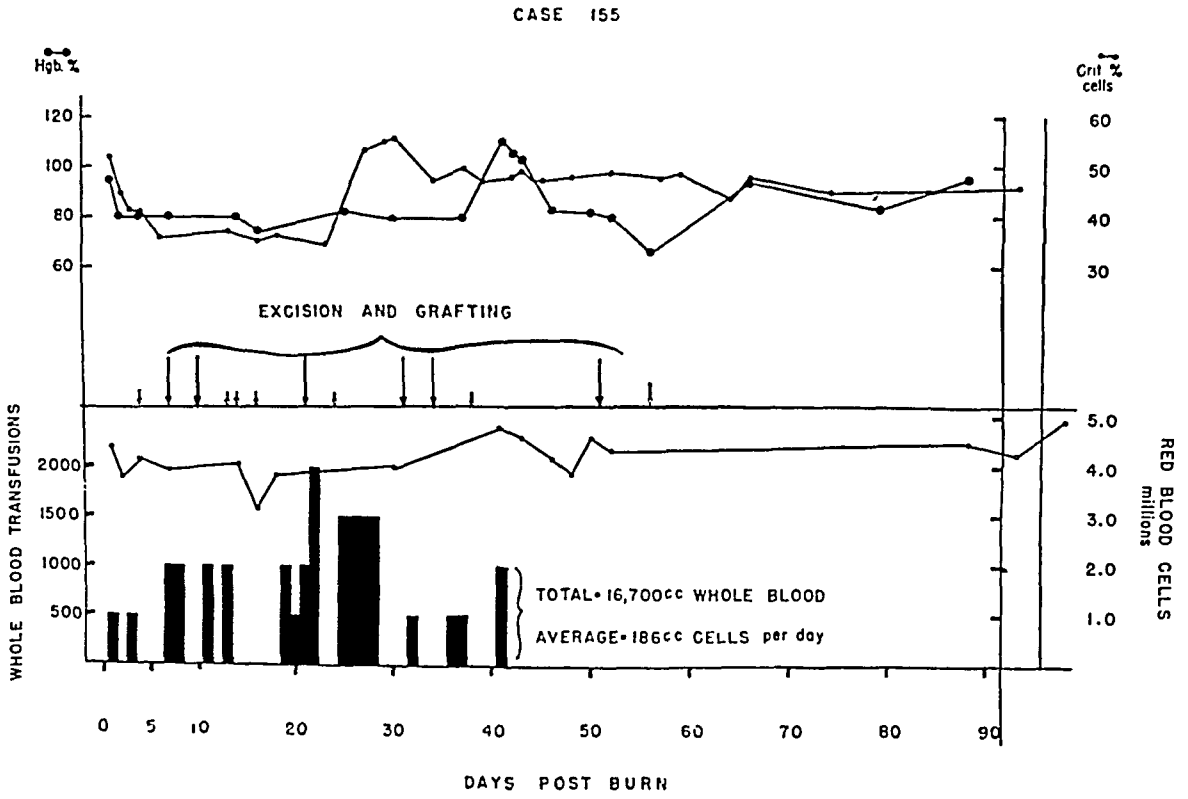



CHART 3.—Case 155: Peripheral blood findings and whole blood transfusions required by a patient with extensive deep burns (41 per cent total, 26 per cent third degree).

The whole blood given according to clinical indications succeeded in maintaining adequate peripheral red cell concentrations despite operations (large arrows) and dressings (small arrows). The amount given, therefore, approximated the requirements, and for the first 42 days averages 186 cc. of cells per day. These requirements included compensation for frank external loss at operation and dressing and for that reason cannot be compared with the red cell balances shown in Charts 5, 6, 7 and 8, which exclude such losses.

Of the latter, nine survived, and could be studied throughout their convalescence; four died of their injury.

### 1. SECOND DEGREE BURNS AND THIRD DEGREE BURNS OF LIMITED EXTENT

The four patients studied showed little tendency towards anemia. Viewed either from the point of view of peripheral cell concentrations, or red cell mass alterations, there is little significant evidence of red cell disappearance. An ex-

ample of the findings in one of these patients (Case 196) who showed no anemia is given in Table II.

One patient of this group (Case 254) had a total burn of 45 per cent and required energetic plasma therapy for the first 48 hours after his burn. The patient was group A. Studies of the two plasma pools used showed no anti-A antibodies in the first and an anti-A antibody titer of 1 : 64 in the second.* This patient alone of the second-degree group showed an increase in the excretion of

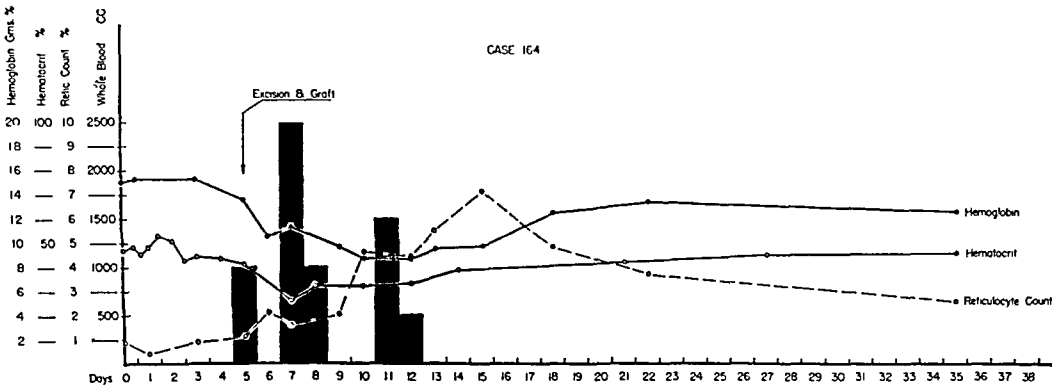



CHART 4.—Case 164: Hemoglobin concentration, hematocrit, reticulocyte response found and transfusions given a patient with moderately severe burns (36 per cent total, 7 per cent third degree).

An anemia became manifest on the sixth day and was not relieved until after the 22d day. Operation on the fifth day was attended by loss of blood presumably inadequately replaced by the 1,000 cc. of whole blood given (vertical black blocks). The red cell volumes (dye technic) were, on entry 2,510 cc., the second day 2,110 cc., and on the seventh day 1,210 cc. Accordingly, on the seventh and eighth days, respectively, 2,500 cc. and 1,000 cc. of blood was given. There was little effect on peripheral hemoglobin concentration and hematocrit but there was a rise in reticulocyte count. On the 11th and 12th days further transfusion again resulted in little immediate change in hematocrit or peripheral hemoglobin concentration but a further rise in reticulocyte count took place. Only after this regenerative response did the peripheral indices rise to normal. The red cell volume on the 27th day was 2,040 cc. These findings suggest (as do those in Case 269, Chart 9) that multiple closely spaced transfusions may be disappointing in their effects on red cell mass. They further indicate that transfusions do not suppress reticulocytosis in such a patient and that marrow regeneration may restore peripheral indices to normal quite rapidly.

urobilinogen in urine and feces during the second week following his burn. The low antibody (isohemagglutinin) titer probably precludes blood destruction from that source as the cause of this pigment excretion.

### 2. EXTENSIVE THIRD DEGREE BURNS

A. *Red Cell Mass (Dye) and Peripheral Blood Findings in Five Patients Surviving Injury:* These five patients are grouped together as the earlier patients studied before the isotope technic became available. Case 155 (Chart 3) demonstrates the amount of whole blood required to avoid anemia in an exten-

* We are indebted to Dr. Louis K. Diamond for these agglutinin studies which in this patient and in three others studied failed to demonstrate significant un-neutralized antibody titer in our plasma pools.

sive third degree burn patient subjected to early surgery. Case 164 (Chart 4) shows the disappointing effect of closely-timed red cell replacements. There is a subsequent rise to normal red cell count, but only after a striking reticulocyte response which was, in all likelihood, responsible for the return to normal. In Table III the total blood replacement required in these patients is shown.

All of these patients show red cell losses of 100-400 cc. per day during their early course; when one calculates the over-all red cell balance (*i.e.*, net volume change minus net replacement) this loss is apparent though its source, whether surgical or physiologic, is not clear. An example of such data is shown in Table IV. All figures in this table are in cubic centimeters of packed red cells; the

TABLE III

WHOLE BLOOD THERAPY IN PATIENTS WITH EXTENSIVE DEEP BURNS—EARLY SURGICAL CLOSURE

| Case Number | Extent Burn Total/3° | Whole Blood Transfusions | Duration of Hospitalization |
|---|---|---|---|
| 135 | 25/15 | 8,050 cc. | 92 days |
| 143 | 40/34 | 13,250 cc. | 122 days |
| 149 | 72/38 | 10,000 cc. | 85 days |
| 155 | 41/26 | 16,700 cc. | 108 days |
| 164 | 36/7 | 6,500 cc. | 60 days |

"loss per day" column indicates the average total loss per day (all sources) in the interval between the determinations. The magnitudes in this category are larger than those in subsequently described red cell balances because they include operative losses, whereas the balances are exclusive of such loss.

B. *Red Cell Mass, Radioiron Studies, Peripheral Blood Findings, and Pigment Excretion in Four Patients Surviving Injury:* The most extensive studies into the causes of the anemia encountered in deep burns were carried out in four patients who entered the hospital within the first hours after injury. All were treated with penicillin from entry. In three the life history of the burn was not disturbed by early operation; in one, excision of dead tissue was carried out on the eighth day after injury. The findings are recorded in detail in the form of case reports.

CASE 210

Case 210.—(Tables V and VI; Charts 5 and 6) : A previously well, 34-year-old housewife, and mother of three, received a flame burn of 31 per cent of her total body surface, 25 per cent of her total surface being a third degree burn. Striking evidence of internal red cell destruction as well as excretion of the end-products of such destruction were demonstrated and the findings correlated well with a somewhat checkered clinical course. Although the patient made a good response to shock therapy, clinically, she seemed sicker during the first week than the extent of the injury would have indicated. On the eighth day an attempt was made to hasten the care of her deep burns and relieve her of the burden of wound infection, by excising the burns under general anesthesia. The wounds proved, in spite of the penicillin, to have developed a deep-seated inflammation and bled profusely on excision. Operation was stopped before half was excised, and none was grafted immediately as had

been planned. Because of the poor clinical reaction to operation, grafting even of the excised area was not started until the twenty-first day. At this time the excised wounds were coated with fiery, infected granulations, while the unexcised were edematous, with evidence of deeper infection. Her later course was one of repeated skin graftings, slow healing, with gradual clinical improvement, and discharge about four months after entry.

*Early Hemolysis:* On the day of admission the patient showed evidence of hemolysis. A hemoglobin concentration of 0.11 Gm./100 cc. in the serum was observed in the first three hours after injury. Such a high level of free hemo-

TABLE IV

RED CELL VOLUMES, TRANSFUSIONS, AND AVERAGE LOSSES PER DAY (IN CUBIC CENTIMETERS OF CELLS)

| Case 143 Male, Age 17, Weight 58.7 Kg. Extent of Burn: Total/40% 3°/34% | | | | Case 149 Male, Age 20, Weight 66.1 Kg. Extent of Burn: Total/72%3°/38% | | | | Case 164 Male, Age 32, Weight 71.2 Kg. Extent of Burn: Total/36% 3°/7% | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | Red Cell Mass (Dye) | Transfusions | Losses Per Day | Day | Red Cell Mass (Dye) | Transfusions | Losses Per Day | Day | Red Cell Mass (Dye) | Transfusions | Losses Per Day |
| 2 | 2,130 | | | 0 | 2,750 | | | 0 | 2,510 | | |
| 6 | 1,650 | 420 | 185 | 2 | 1,920 | | 400 | 2 | 2,110 | 420 | 410 |
| 40 | 1,600 | 4,750 | 140 | 6 | 2,350 | 840 | 120 | 7 | 1,210 | 1,125 | 400 |
| 65 | 1,890 | 1,125 | 34 | 42 | 2,380 | 3,260 | 90 | 27 | 2,040 | 1,125 | 15 |
| | | | | 85 | 2,220 | | | | | | |

PERIPHERAL BLOOD FINDINGS

| Day | R.B.C. Millions | Hb. Gm. | Hematocrit % Cells | Day | R.B.C. Millions | Hb. Gm. | Hematocrit % Cells | Day | R.B.C. Millions | Hb. Gm. | Hematocrit % Cells |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 6.45 | | 55 | 0 | | | 70 | 0 | 5.60 | 18.4 | 47 |
| 2 | 5.40 | | 47 | 1 | | | 57 | 1 | 4.90 | 17.6 | 49 |
| 3 | 5.07 | | 44 | 2 | | | 50 | 3 | 4.50 | 15.1 | 44 |
| 5 | 3.82 | 14.4 | 42 | 4 | 5.00 | 12.8 | 30 | 7 | 3.00 | 11.0 | 28 |
| 7 | 5.53 | 14.2 | 40 | 6 | 5.60 | 11.2 | 42 | 13 | 3.80 | 9.4 | 39 |
| 10 | 3.60 | 9.6 | 37 | 9 | 3.80 | 11.2 | 35 | 18 | 3.80 | 12.5 | 42 |
| 16 | 3.53 | 14.4 | 49 | 13 | 4.38 | 11.2 | 39 | 35 | 5.10 | 12.5 | 46 |
| 27 | 3.53 | 9.6 | | 25 | 4.20 | 12.8 | | 42 | | | 45 |
| 34 | 4.34 | 13.6 | 40 | 42 | 4.40 | 13.0 | 48 | 51 | | | 50 |
| 45 | 4.54 | 14.4 | 45 | 52 | 4.20 | 12.8 | 45 | | | | |
| 75 | 4.80 | 14.4 | 48 | 85 | | | 49 | | | | |
| 103 | 4.64 | 15.5 | 54 | | | | | | | | |

globin in the serum points to a comparatively large initial destruction of red cells. Only one patient of our series showed a greater concentration, 0.17 Gm./100 cc. in Case 234. The volume of red cells destroyed cannot be computed accurately from the concentration of free hemoglobin in the serum.*

* Hemoglobin injected into the blood stream as free hemoglobin[12] is rapidly removed and it is impossible from the serum value to calculate the total amount released by hemolysis if the hemolysis continues over a period of hours. If the serum concentration is multiplied by the plasma volume, it yields a figure of only 1.9 Gm. of hemoglobin, an obviously low figure. It would probably be more accurate to multiply the concentration by the volume of the entire extracellular space because hemoglobin, being a protein of low molecular weight (68,000), probably equilibrates into the extracellular space even more rapidly than albumin. Its rapid removal by the spleen, marrow, liver and kidney, makes any such calculation but an estimate.

*Internal Red Cell Disappearance:* The red cell balance, based on periodic measurements of the red cell mass, the addition of all cells lost by sampling and at operation and the subtraction of all given by transfusion, showed an early rapid and later slow disappearance of red cells from the circulation (Table V and Chart 5).

Reference to Table V shows, first, that the dye method for the measurement of the red cell mass checks well with the radioactive technic except in the early phase immediately following the burn. In this phase the presence of abnormal

TABLE V

Case 210

Female, Age 34, Weight 73 Kg.

Extent of Burn: 31 per cent total, 25 per cent third degree

RED CELL BALANCE

| Period | Days After Injury | Red Cell Mass | | Red Cell Accounts | | | Red Cell Balance Change Per Day | |
|---|---|---|---|---|---|---|---|---|
| | | Dye Method | Radioactive Method | Transfusions Given | Samples Taken | Op. + Dressing Losses | Dye Method | Radioactive Method |
| I | 0— 5 | 2010—(880) | 1535—1370 | 263 | 68 | 0 | | — 90 |
| II | 5— 8 | (880)—2100 | 1370—2100 | 756 | 18 | 0 | | — 3 |
| III | 8— 15 | 2100—2590 | 2100—2110 | 2118 | 39 | 730 | —122 | —191 |
| IV & V | 15— 34 | 2590—1560 | 2110—1410 | 1600 | 87 | 813 | — 91 | — 74 |
| VI | 34— 49 | 1560—1660 | 1410—1440 | 185 | 52 | 250 | + 16 | + 11 |
| VII | 49— 64 | 1660—2150 | 1440—1820 | 486 | 28 | 450 | + 32 | + 25 |
| VIII | 64— 86 | 2150—1860 | 1820—1720 | 52 | 25 | 68 | — 11 | — 3 |
| IX | 86—114 | 1860—1850 | 1720—1440 | 0 | 0 | 0 | 0 | — 10 |
| X | 114—127 | 1850—2130 | 1440—(800) | 0 | 0 | 0 | + 22 | |

(All figures are in cubic centimeters of packed red cells.)

RADIOIRON UTILIZATION

| Period | Days After Injury | Radioiron Utilization Per Cent | Per Cent of Normal Utilization |
|---|---|---|---|
| V | 28— 34 | 45.0 | 65.0 |
| IX | 93—102 | 47.2 | 68.0 |

capillary permeability in the wound and hemoglobin or other pigments in the serum may render the dye determination untrustworthy. The table shows, second, under "Red Cell Accounts," the enormous volumes of blood which may be lost by operative excision of a wound eight days after injury from granulating wounds into dressings and in grafting. The figure of 730 cc. in Period III under "Operation and Dressing Losses" represents 1,750 cc. of whole blood lost during the excision of slough. The subsequent figures show how large in aggregate may be the continued small loss into dressings and from grafting. A loss of 75 to 150 cc. of whole blood was determined each time the dressings were changed and a loss up to 200 cc. with each grafting.

The third section of Table V, "Red Cell Balance," details the average loss, or gain, of red cells per day after proper adjustment has been made for transfusions, sampling and dressing and operation loss. In the first five days,

Period I, there was an average disappearance of 90 cc. of red cells per day. From the fifth to eighth days, Period II, an approximate balance was achieved. Immediately following the wound excision, which took place between Periods II and III, there was a severe loss of circulating red cells which lasted through Period V. For the week of Period III approximately 200 cc. of red cells disappeared each day, while in the subsequent 19 days of Periods IV and V an average of 75 cc. per day could not be accounted for. It would appear that the

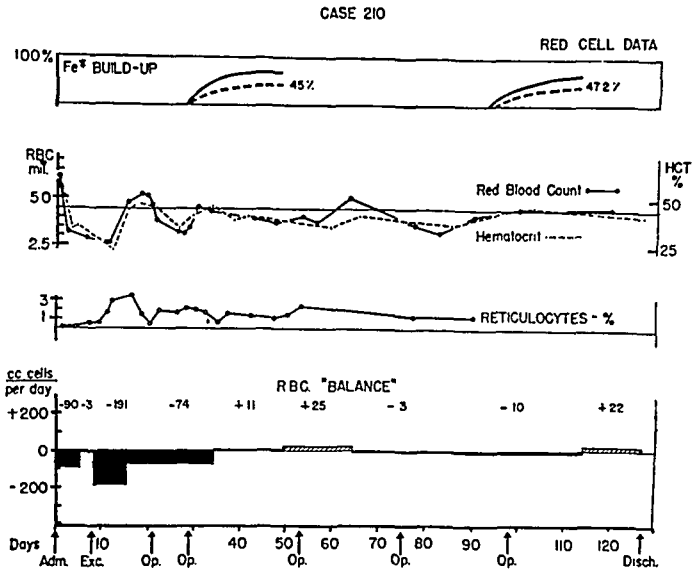



CHART 5.—Case 210: Radioiron utilization, peripheral blood findings and red cell balance demonstrating early progressive red cell destruction in a severely burned patient (31 per cent total, 25 per cent third degree).

The radioiron utilization curves (Fe* build-up) are diagrammatically shown. The solid line indicates the normal curve of 70 per cent utilization. The dotted lines indicate the observed values and on both occasions demonstrate some bone marrow depression due either to iron deviation or toxic depression of the bone marrow.

Red cell counts, hematocrit and reticulocyte counts show an early profound anemia followed by a reticulocyte rise, and later, maintenance of nearly normal peripheral indices.

The red cell balance (cf. Table V) is an expression of the net red cell formation or destruction as elucidated by serial measurements of the red cell mass. In this patient an early destruction is followed by a period of little change (average destruction of 3 cc. of cells per day) and then a secondary red cell destruction correlated in appearance with a partial excision of the burn wound.

Subsequent to the 35th day, destruction and formation are equally balanced, and there is less significant net change in red cell mass.

operative procedure, whether by a nonspecific incitation of metabolic changes or by kindling the infection, had tipped off this renewed internal or hidden red cell destruction which lasted three and a half weeks.

Throughout the second month after injury, Periods VI and VII, this patient achieved a positive balance of red cells; that is, she was able to make more than she was destroying internally. At the beginning of the second month, however, there was again evidence of internal red cell disappearance with a slight negative balance lasting for seven weeks, Periods VIII and IX.

*Peripheral Blood Correlation:* The examination of the peripheral blood by red blood cell count, hematocrit and hemoglobin concentration (Table VI and Chart 5) revealed for the greater portion of the period of hospitalization a close correlation between the red cell mass and the anemia in the peripheral blood. Only from the second to eighth day, when there was evidence of an enlarged plasma volume, did the peripheral anemia exceed the observed fall in red cell mass; such an anemia is, therefore, termed false. Two and a half months after entry the patient again developed a peripheral anemia, at the time when her red

TABLE VI

Case 210
Female, Age 34, Weight 73 Kg.
Extent of Burn: 31 per cent total, 25 per cent third degree

SERUM HEMOGLOBIN

| Day + Hour Post-Burn | Hemoglobin Gm./100 Cc. Serum |
|---|---|
| 0+2.5 | 0.11 |
| 0+3 | 0.11 |
| 0+4 | 0.10 |
| 0+4.5 | 0.06 |
| 0+7.5 | 0.02 |

PERIPHERAL BLOOD EXAMINATIONS

| Day Post-Burn | R.B.C. Millions | Hemoglobin Gm./100 Cc. | Hematocrit % Cells | Reticulocytes % |
|---|---|---|---|---|
| 0 | 6.04 | 17.7 | 58 | |
| 1 | | 16.3 | 51 | |
| 2 | 3.25 | 13.5 | 44 | |
| 3 | | | 35 | |
| 4 | | | 37 | |
| 5 | | | 34 | |
| 6 | 2.91 | 12.0 | 36 | 0.6 |
| 11 | 2.64 | 8.0 | 25 | 1.7 |
| 15 | 1.80 | 16.8 | 44 | 3.5 |
| 21 | 3 85 | 14.0 | 44 | 2.0 |
| 26 | 3.26 | 13.5 | 34 | 1.2 |
| 34 | 4.30 | 17.0 | 42 | 0.8 |
| 42 | | 15.0 | 41 | 1.5 |
| 50 | 4.95 | 14.0 | 35 | 1.6 |
| 53 | 4.08 | 14.3 | | 2.7 |
| 56 | 2.82 | 12.0 | 35 | |
| 63 | 5.06 | 14.5 | 41 | |
| 77 | 3.70 | 13.0 | | 1.5 |
| 82 | 3.20 | 13.8 | | |
| 93 | 4.15 | 12.5 | 41 | 1.5 |
| 114 | | | 39 | |
| 127 | | | 40 | |

cell balance reverted to slight negativity. This anemia was repaired coincident with complete healing.

*Excretion Products of Red Cell Destruction:* Studies of the excretion of the end-products of red cell destruction in this patient (Chart 6) were illuminating as they corroborated in a satisfactory way the measurements already described of the patient's circulating red cell mass. During the first two weeks the patient was in the hospital, she showed consistently positive benzidine test in the feces, indicating that some hemoglobin or heme was being excreted intact

into the gastro-intestinal tract either through the biliary apparatus or through the large bowel mucosa. This is a constant finding in burn patients and has previously been reported,[13] but this patient demonstrated the phenomenon to an unusual degree and for a protracted period. The urine urobilinogen excretion is somewhat elevated on the first observation and then on the tenth day, shortly after the period of zero red cell balance the urine urobilinogen returned to normal.

*Radioiron Utilization:* During the course of the patient's convalescence, starting on the twenty-eighth day and again on the ninety-third day, two radio-

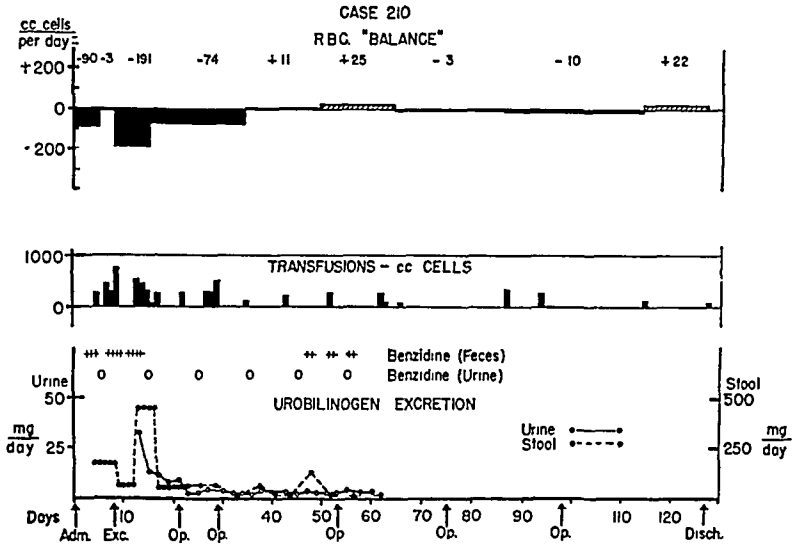



CHART 6.—Case 210: Red cell balance, transfusions and pigment excretion in the same severely burned patient as in Chart 5.

The red cell balance is repeated for orientation. The transfusions, recorded in cubic centimeters of cells, were administered according to clinical indications. It is apparent that their timing follows each of the first two periods of red cell destruction indicated by negative red cell balances.

The urobilinogen excretions are shown in milligrams per day in urine and stools. There is an increased excretion of this end-product of hemoglobin metabolism up to the 15th day, after which it is essentially normal.

Benzidine-reacting material is present in feces in the early period of destruction; the urine benzidine is consistently negative.

iron build-up curves were carried out, both of which showed some depression of bone marrow activity. The first curve showed 45 per cent utilization of the radioiron, which is only about 65 per cent of normal, and the second build-up curve showed 47.2 per cent utilization of the iron which is about 67.5 per cent of normal. As the result of these tests of marrow function a part of the anemia tendency late in the convalescence of this patient may be interpreted as due to inadequate bone marrow response. This, in turn, may be due to one of two factors, either inadequate supply to the marrow of hemoglobin precursors, especially iron, or secondly, alteration in bone marrow function as a result of the presence of a large, infected open wound. The iron utilization curves do not indicate which mechanism was operating.

*Reticulocyte Response:* During the maximal period of red cell destruction of the secondary anemia phase, the patient's reticulocyte response rises to 3 per cent in the peripheral blood and is maintained near 1 per cent for approximately two months, indicating little marrow activity as shown also by the poor radioiron utilization.

*Summary and Discussion:* This patient showed every laboratory and clinical evidence of massive internal red cell destruction. Many transfusions were required to maintain peripheral red cell concentrations within the normal range. There was slight evidence of bone marrow response, as indicated by the reticulocyte count, but this bone marrow response was probably subnormal, as indicated by the impaired utilization of radioactive iron.

TABLE VII

Case 217
Female, Age 26, Weight 92.8 Kg.
Extent of Burn: 78 per cent total, 45 per cent third degree

RED CELL BALANCE

| Period | Days Post-Burn | Red Cell Mass: Dye Method | Red Cell Mass: Radioactive Method | Red Cell Accounts: Transfusions Given | Red Cell Accounts: Samples Taken | Red Cell Accounts: Op. + Dressing Losses | Red Cell Balance Change Per Day: Dye Method | Red Cell Balance Change Per Day: Radioactive Method |
|---|---|---|---|---|---|---|---|---|
| I | 0— 3 | 2320—1410 | —1380 | 742 | 59 | 0 | —318 | |
| II | 3—11 | 1410—1690 | 1380—1250 | 45 | 63 | 0 | + 50 | —19 |
| III | 11—16 | 1690— | 1250—1930 | 742 | 43 | 135 | | +23 |
| IV | 16—25 | —2160 | 1930—1830 | 101 | 10 | 0 | — 14 | —21 |
| V | 25—49 | 2160—2200 | 1830—2150 | 1850 | 85 | 531 | — 50 | —38 |
| VI | 49—71 | 2200—2160 | 2150—2010 | 1470 | 25 | 157 | — 60 | —65 |
| VII | 71—98 | 2160—(1660) | 2010—2240 | 97 | 59 | 202 | | +15 |

(All figures are in cubic centimeters of packed red cells.)

RADIOIRON UTILIZATION

| Period | Post-Burn | Radioiron Utilization Per Cent | Per Cent of Normal Utilization |
|---|---|---|---|
| I | 0— 5 | 15.0 | 21.0 |
| V | 31—36 | 59.0 | 84.0 |
| VII | 80—85 | 70.0 | 100.0 |

It is difficult to know what rôle the operative procedure on the eighth day played in this anemia which became so much intensified after the operation. It should be emphasized again that the figures for red cell balance are over and above the operative and dressing losses and that, therefore, the increase in anemia tendency after the operation must be related either to continued insensible red cell loss into the wound or to some alteration in metabolism, possibly related to the alarm reaction following the operation. In any event, it is apparent that this patient needed one whole blood transfusion every three days in the first week and an average of one every two days in the next three weeks in order to maintain a constant red cell mass, entirely apart from the blood needed to replace operative and dressing losses.

CASE 217

Case 217.—(Tables VII and VIII; Charts 7 and 8): While tending a coal stove, the clothes of a robust, well-nourished single woman, age 26, caught on fire; 78 per cent of her body surface was burned, 45 per cent of the total body surface being of full-thickness destruction. Shock was successfully prevented with massive doses of plasma intravenously and an equivalent volume of oral fluids. During the phase of gradual resorption of the edema from the interstitial space, her kidneys were able to keep pace by a huge volume output and she had, therefore, only moderate and nonincapacitating hemodilution. Penicillin, in large doses, was started at entry and it was planned to start the excision and grafting of

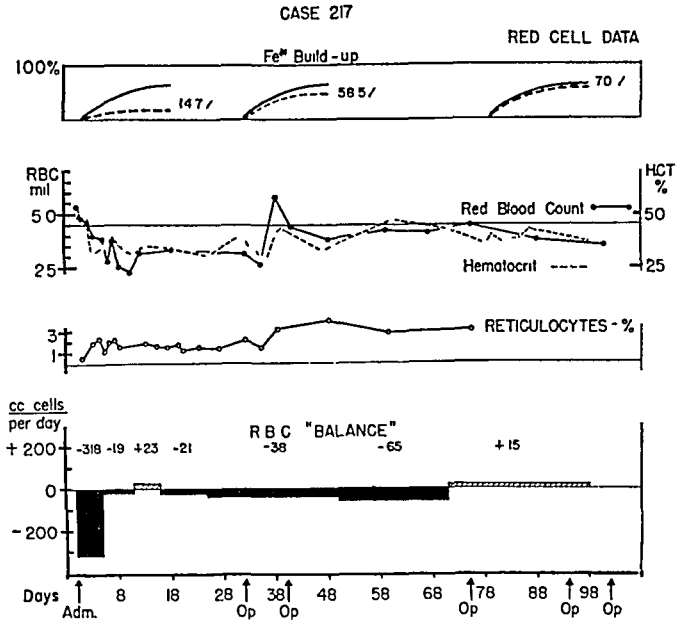



CHART 7.—Case 217: Radioiron utilization, peripheral blood findings and red cell balance demonstrating an early and late progressive anemia in an extensively and deeply burned patient (78 per cent total, 45 per cent third degree).

The radioiron utilization ($Fe^{59}$ build-up) is shown diagrammatically as in Chart 5 (Case 210). The first test done on entry showed little elaboration into peripheral erythrocytes, correlating with the relative lack of reticulocyte response; about the 30th day marrow function had improved, evidenced by better iron utilization as well as increase of reticulocytes to 4 per cent. By the 85th day utilization was normal.

The peripheral counts demonstrate an early profound anemia with relatively little reticulocyte response, followed about the 35th day by a rise with reticulocyte increase coincident with massive transfusion. Thereafter, nearly normal levels were maintained.

The red cell balance is shown as in Chart 5 (Case 210). There is an early massive red cell loss (internal destruction) followed by relative balance until about the 50th day when, for about three weeks, cell disappearance increased again. After this period a slightly positive balance obtained.

the full-thickness wounds on the seventh day. Fever appeared early, however, and had risen to 103° F. by the day before the intended operation. Widespread, moderately invasive infection beneath the deep burns (despite penicillin) was evident at change of the dressings and plans for early operative closure were abandoned. Grafting was eventually accomplished on the granulating base left after spontaneous separation of the slough. The first grafting was done on the fortieth day. The course of this patient was, therefore, less trammeled by operations than Case 210 and the anemia is more characteristic of that which is to be expected as the consequences of the burn alone.

*Early Hemolysis:* On the day of her burn the patient showed free hemoglobin in the serum to the extent of 0.12 Gm./100 cc., evidence of early red cell destruction.

*Internal Red Cell Disappearance:* The data on red cell volumes in this patient are shown in Table VII. A radioactive red cell volume was not determined on admission because it was decided instead to carry out an early build-up curve. However, in the patient's first five days, there is a marked destruction of red cells as indicated by the dye method, and as will be seen below this was correlated with urobilinogen excretion and doubtless represents the true situation.

After this initial destruction, the patient goes into a much less spectacular secondary phase than was the case with the previous patient. There is a de-

TABLE VIII

Case 217
Female, Age 26, Weight 92.8 Kg.
Extent of Burn: 78 per cent total, 45 per cent third degree

SERUM HEMOGLOBIN

| Day + Hour Post-Burn | Hemoglobin Gm./100 Cc. Serum. |
|---|---|
| 0 + 1 | 0.12 |
| 0 + 1.5 | 0.10 |
| 0 + 2.5 | 0.10 |

PERIPHERAL BLOOD EXAMINATIONS

| Day Post-Burn | R.B.C. Millions | Hemoglobin Gm./100 Cc. | Hematocrit % Cells | Reticulocytes |
|---|---|---|---|---|
| 0 | 5.30 | 16.0 | 43 | |
| 1 | 4.90 | 18.0 | 39 | 1.2 |
| 2 | 4.80 | 13.6 | 47 | 0.0 |
| 3 | 4.00 | 10.4 | 33 | 2.1 |
| 4 | 2.90 | 12.8 | | 2.5 |
| 5 | 3.91 | 13.0 | 35 | 1.1 |
| 8 | 3.00 | 10.0 | 35 | 1.9 |
| 15 | | 13.5 | | 1.8 |
| 24 | | 12.5 | | 1.3 |
| 32 | 3.26 | 11.7 | 40 | 2.2 |
| 48 | 3.83 | 11.5 | 34 | 4.0 |
| 67 | 4.20 | 14.2 | | |
| 88 | 3.87 | 12.0 | | 0.3 |
| 101 | 3.51 | 9.8 | | |
| 123 | 4.35 | 14.5 | | |
| 179 | 4.50 | 14.4 | | |

struction of red cells varying from 20 to 60 cc. a day for the next two months before the patient finally achieves a positive red cell balance.

*Peripheral Blood Correlation:* The determinations of the degree of anemia in the peripheral blood (Table VIII, and Chart 7) in this as in the previous patient followed closely the observed red cell mass except during the phase of hemodilution. This phase, or period of false anemia, was encountered from the second through approximately the eleventh day.

*Excretion Products of Red Cell Destruction:* The data of the excretion of the products of red cell destruction are shown in Chart 8. The excretion of urobilinogen in the urine is initially normal. The subsequently elevated values overlap the periods of red cell destruction. It appears both from the onset and the downward slope of the initial curve that there is a latent period (about 48 hours) between the release of hemoglobin in the circulation and the appearance of

unusual amounts in the urine as urobilinogen. Then from the eighth to sixteenth hospital day, shortly after the period when the patient was in transient zero balance, the urine-urobilinogen was normal. From the eighteenth to the sixtieth hospital day there were intermittent rises in urine-urobilinogen when the patient was destroying 20 to 60 cc. of cells per day. On the twentieth day a cystitis was recognized. There was no rise in excretion following the first grafting on the fortieth day but there was a peak the day

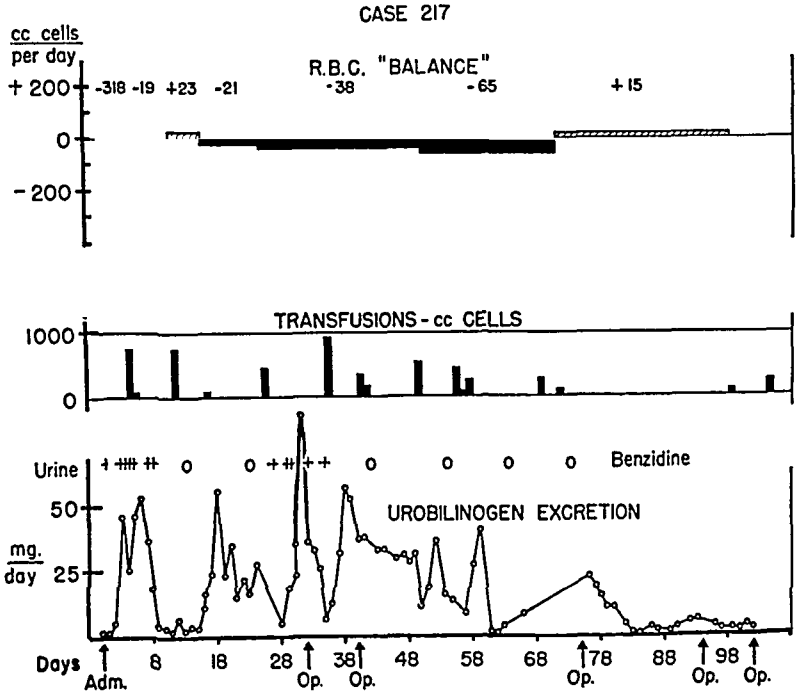



CHART 8.—Case 217: Red cell balance, transfusions and pigment excretion in the same severely burned patient as in Chart 7.

The red cell balance is repeated for orientation.

Transfusions (recorded in cubic centimeters of cells) were administered according to clinical necessity, and in this case there was no external loss from early operative excision.

Pigment excretion in the urine shows a striking rise, starting four days after entry, presumably in response to the early internal destruction shown by the negative balance. Excretion returns to normal on the ninth day only to rise again and remain elevated with occasional peaks until the 85th day, when, with slightly positive red cell balance internal destruction has evidently ceased.

Benzidine-reacting material is excreted in the urine coincident with the urobilinogen peaks.

following grafting of the back on the seventy-fifth day. After the eightieth hospital day the urine excretion figures remain in the normal range despite further surgery.

The urine shows a positive benzidine test during the high peaks of urobilinogen excretion indicating that either heme or hemoglobin is being excreted in the urine along with the metabolic end-product, urobilinogen.

*Radioiron Utilization:* The regenerative activity of the bone marrow was tested during three stages of the patient's convalescence. Radioiron was injected intravenously the day of entry and its elaboration into circulating red cells was

observed during the succeeding six days (Table VII and Chart 7). (In order to make this measurement, no radioactive transfusions were given during these days.) Only 21 per cent of the expected activity appeared in the circulation, indicating a severely depressed activity of the marrow. The second injection of radioiron was made on the thirty-first day. The marrow was more active than before but still somewhat depressed, the elaboration of the iron being 84 per cent of the expected normal. Such marrow synthesis is interesting in view of the extensive areas of open infected wounds. Six weeks later, two and a half months after entry, activity of the bone marrow was normal as judged by the third injection of radioiron.

*Reticulocyte Response:* The rise in bone marrow function as indicated by the second injection of radioiron was accompanied by a reticulocyte response from 2 to 3 per cent, and later 4 per cent (Chart 7).

*Summary and Discussion.*—As did the previous patient, this extensively and deeply burned patient showed evidence of massive internal destruction of red cells. Also, like the previous patient, she passed through a prolonged period of disordered physiology, with high fever, water retention and severe clinical illness. Both patients developed large open wounds.

Both showed an early acute red cell destruction of 100 to 300 cc. per day and lasting about four days. This phenomenon is interpreted as being the destruction of red cells whose viability had probably been altered by exposure to heat while circulating in the burned area at the time of the burn, though we have no proof of the veracity of this interpretation.

After this initial destruction, both patients show a transient period of essentially zero red cell balance followed by a secondary phase of red cell destruction not as spectacular as the early loss. In the first patient this secondary phase is quite acute, apparently related to the operative procedure carried out at that time. No such operation was carried out in this second patient and her later curve is smoother. Both patients showed late destruction far on into their convalescence which is correlated with occasional relapses of their anemia. An increased urobilinogen excretion corroborated the data derived from the volume measurements. Evidence of bone marrow suppression was found in both patients as subnormal levels of iron utilization. The reticulocyte counts correlated with the observed changes in iron elaboration but did not give indication in themselves, therefore, of the degree of deficiency of the red cell mass.

### Case 260

Case 260.—While celebrating her impending departure for a tuberculosis sanitarium, the clothes of a 27-year-old, childless housewife, caught on fire, burning 28 per cent of her body surface, 12 per cent of her total surface showing full-thickness destruction. In anticipation of her developing a progressive anemia it was planned at entry to follow the erythrocyte changes and postpone all possible influences, such as transfusion and early operation, until the nature of the anemia was established. Her red cell mass was immediately measured with radioactive red cells. Her wounds were dressed without débridement or cleansing, and she was started on penicillin. The first grafts were placed on freshly excised wounds on the ninth day. The remaining areas were grafted at approximately weekly intervals, and the patient was discharged at the end of three months.

To our surprise she developed no true anemia. It was also true that she never developed a negative nitrogen balance. Both of these findings may be attributed to the relative absence of invasive infection and to a continuously good appetite.

From the third to the fifth days a mild anemia was observed in the peripheral blood. This was interpreted as a false anemia since the red cell mass (by radioactive technic) at entry was 1,475 cc., and seven days later 1,490 cc. Between these virtually identical determinations, 138 cc. of cells had been removed in sampling and no transfusion had been given. Though no significant alteration in the red cell mass was observed, there is evidence of excretion of the end-products of red cell destruction in supernormal quantities. From her fifth to

TABLE IX

Case 269
Male, Age 60, Weight 89 Kg.
Extent of Burns: 27 per cent total, 20 per cent third degree

PERIPHERAL BLOOD EXAMINATIONS

| Day Post-Burn | R.B.C. Millions | Hemoglobin Gm./100 Cc. | Hematocrit % Cells | Reticulocytes % |
|---|---|---|---|---|
| 1 | 5.63 | | 59 | 1.1 |
| 2 | 5.09 | | 47 | 1.4 |
| 4 | 4.09 | | 40 | 1.1 |
| 6 | 4.68 | | 39 | 1.0 |
| 8 | 4.20 | 11.2 | 35 | 1.0 |
| 10 | 3.20 | | 37 | |
| 20 | 3.50 | | 34 | 1:0 |
| 30 | 3.90 | | 39 | |
| 47 | 3.95 | 11.5 | 38 | 0.5 |
| 68 | 4.00 | 9.5 | | 1.0 |

tenth days the patient excreted, intermittently, slightly increased amounts of urobilinogen, the first peak being on the fifth and sixth days and the second peak following immediately her excision and grafting on the ninth day. Associated with this evidence is the presence of weakly positive benzidine-reacting material in the urine from the second to the seventh days, the period during which, it will be recalled, she showed a transient peripheral anemia. It is also of interest that during the latter phase of this period, the patient showed a definite reticulocyte response, suggesting that from the tenth day forward, her bone marrow could compensate for any red cell destruction.

### CASE 269

Case 269.—(Tables IX, X and XI; Chart 9): This patient, age 60, apparently drunk when trying to fill a kerosene stove, was burned when his oil-soaked trousers ignited. Burned around the legs and lower trunk, he crawled into bed and was seen first by a doctor the next day. Twenty hours after injury he reached the hospital, showing extensive deep burns of the legs, buttocks, scrotum and perineum. It was estimated that 27 per cent of the body surface was burned, three-quarters of the burns being full-thickness.

Whole blood-transfusions and early operation were purposely withheld in order to learn the character of the anticipated anemia. The patient was given penicillin intramuscularly. The burn slough was allowed to separate spontaneously and the first grafts were

applied on the thirty-sixth day. Subsequent graftings were accomplished periodically. The patient was discharged on the one hundred and twenty-sixth day.

*Early Hemolysis:* There was no elevation of serum hemoglobin on admission to the hospital.

*Internal Red Cell Disappearance:* The circulating red cell mass was measured by the radioactive technic four times during the patient's convalescence.

TABLE X

Case 269
Male, Age 60, Weight 89 Kg.
Extent of Burn: 27 per cent total, 20 per cent third degree

URINARY EXCRETION OF BILE PIGMENT

| Day Post-Burn | Urobilinogen Mg./24 Hr. | Benzidine |
|---|---|---|
| 0 | 0.0 | |
| 1 | 13.6 | — |
| 2 | 8.2 | ± |
| 3 | 6.2 | ± |
| 4 | 17.4 | ± |
| 5 | 23.9 | — |
| 6 | 13.4 | — |
| 7 | 7.4 | — |
| 8 | 5.8 | — |
| 9 | 14.8 | — |
| 10 | 14.0 | — |
| 11 | 17.3 | — |
| 12 | 8.3 | — |
| 13 | 9.5 | — |
| 14 | 8.2 | — |
| 15 | 8.7 | — |
| 16 | 8.7 | — |
| 17 | 6.6 | — |
| 18 | 10.8 | — |
| 19 | 6.1 | — |
| 20 | 4.2 | — |

TABLE XI

Case 269
Male Age 60, Weight 89 Kg.
Extent of Burn: 27 per cent total, 20 per cent third degree

RED CELL BALANCE

| Period | Day Post-Burn | Red Cell Mass (Radioactive) | Transfusions | Samples Taken | Red Cell Balance |
|---|---|---|---|---|---|
| I | 0–12 | 2780–1773 | 0 | 150 | —72 |
| II | 12–25 | 1773–2077 | 147 | 40 | +15 |
| III | 25–34 | 2077–2564 | 1311 | 150 | —85 |

(All figures are in cubic centimeters of packed red cells).

The measurements were made on the day of entry, the twelfth, twenty-fifth and thirty-fourth days. During the first 12 days, between the initial and second volume studies, there was a disappearance of 857 cc. of red cells, or 72 cc. of cells per day. The disappearance of these cells was shared in equal proportion by the patient's cells and those from the radioactive donor. Since the latter were not in the body at the time of the injury, this disappearance presumably was not the direct result of heat on cells.

During the second period, between the second and third red cell volume determinations, the patient showed a net red cell gain averaging 15 cc. of cells per day, and the concentration of radioactivity of his circulating cells slowly decreased as further evidence of regeneration. In the third period, between

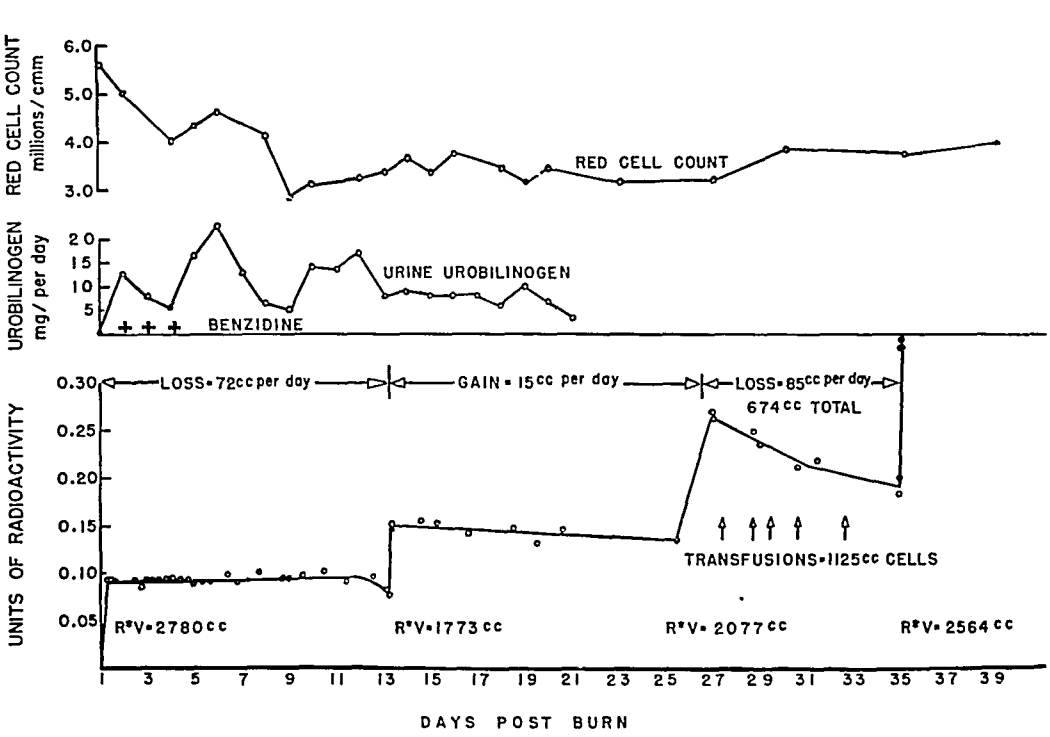



CHART 9.—Case 269: Red cell counts, urobilinogen excretion and radioiron data showing an early progressive anemia in a severely burned patient (27 per cent total, 20 per cent third degree).

Whole blood transfusions were withheld until the 27th day post-burn except as necessary to measure the red cell mass (R*V). To such purpose, radioactive transfusions were given on the first, 13th, 26th and 35th days. A peripheral anemia developed in the first ten day with a falling red count, evidence of increased urobilinogen excretion and a loss of 72 cc. of cells per day (average) during the first two weeks. During this time the radioactivity of the patient's red blood cells (resulting from an active transfusion the first day) did not alter significantly, indicating that his own cells and those of the radioactive donor partook equally of the destruction.

From the 13th to 26th day the red cell count remained stationary, urobilinogen excretion was not elevated, and the patient showed an over-all gain of 15 cc. of cells per day (average); the peripheral radioactivity fell slightly, indicating active regeneration sufficient to prevent further anemia but not sufficient to compensate entirely for previous cell losses.

Starting on the 27th day the patient was given five transfusions totalling 1,125 cc. of cells. The red count rose very little and the red cell mass increased only 500 cc. (The drop in radioactivity was due to dilution of the active cells by bank blood, cf. Chart 1.) The findings suggest that multiple closely spaced transfusions may give disappointing results in terms of red cell mass changes.

his third and fourth cell volume determination, the patient was given five whole blood transfusions, totalling 1,125 cc. of cells, as well as the small amount of radioactive cells given him, but the total increment in volume was only about 500 cc. The calculated destruction of cells during this period is 674 cc. The

period involved is eight days long and the cell destruction per day, therefore, averaged 85 cc.

The reason for this massive disappearance of red cells and failure to rebuild completely the red cell mass is not clear. The downward slope of the curve of concentration of radioactivity in this last period of observation is what should be expected from the increase in size of the red cell mass, the radioactive cells remaining in the circulation. Whether the entire disappearance was at the expense of the recently transfused cells cannot be determined from the findings. The patient showed no untoward clinical reaction to his transfusions.

*Excretion Products of Red Cell Destruction:* The disappearance of red cells in the initial period was accompanied by a rising excretion of urobilinogen which reached a peak on the fifth day after injury of 23.9 mg. Following this

TABLE XII

Case 234
Male, Age 68, Weight 60 Kg.
Extent of Burn: 55 per cent total, 45 per cent third degree

RED CELL VOLUMES, TRANSFUSIONS, AND RED CELL BALANCE

| Day Post-Burn | Red Cell Mass (Radioactive) | Transfusions | Samples Taken | Red Cell Balance |
|---|---|---|---|---|
| 0 | 2030 | | | |
| 3 | 1600 | 75 | 59 | 148 |
| 7 | 1420 | 300 | 76.5 | 100 |

(All figures are in cubic centimeters of packed red cells.)

| Day + Hour Post-Burn | Serum Hemoglobin Gm./100 Cc. |
|---|---|
| 0 + 8 | 0.16* |

* Earlier serum hemoglobin estimations showed larger amounts of hemoglobin to be present, but a quantitative result was not obtained because of the inaccuracy of the colorimeter in dealing with high hemoglobin concentrations in undiluted serum.

peak there was a gradual decline during the 20 days the measurements were made. There was but a transient and early excretion of benzidine-positive material in the urine.

*Summary and Discussion:* This patient showed two periods of red cell destruction with a period of red cell regeneration and increase in red cell mass between. The early period of destruction and the relative constancy of red cell radioactivity constitutes evidence that in this patient, at least, the anemia was not due to selective destruction of the patient's own cells on the basis, for instance, of heat sensitization or fragility. It suggests that the red cell destruction included proportionately both the patient's own (burned) cells and those (unburned) infused from the radioactive donor.

The later period of destruction demonstrates the occasional costliness of repeated transfusions. More than half of the volume of cells given in five transfusions disappeared during the eight days during which they were administered.

C. *Red Cell Mass, Radioiron Studies, Peripheral Blood Findings and Pigment Excretion in Four Patients Not Surviving Injury:* The four extensively and deeply burned patients of this group are of considerable interest due to variations from the preceding group of surviving patients.

Case 234.—(Table XII): An elderly man showed all the phenomena we have come to associate with the burn anemia—hemoglobinemia, hemoglobinuria,

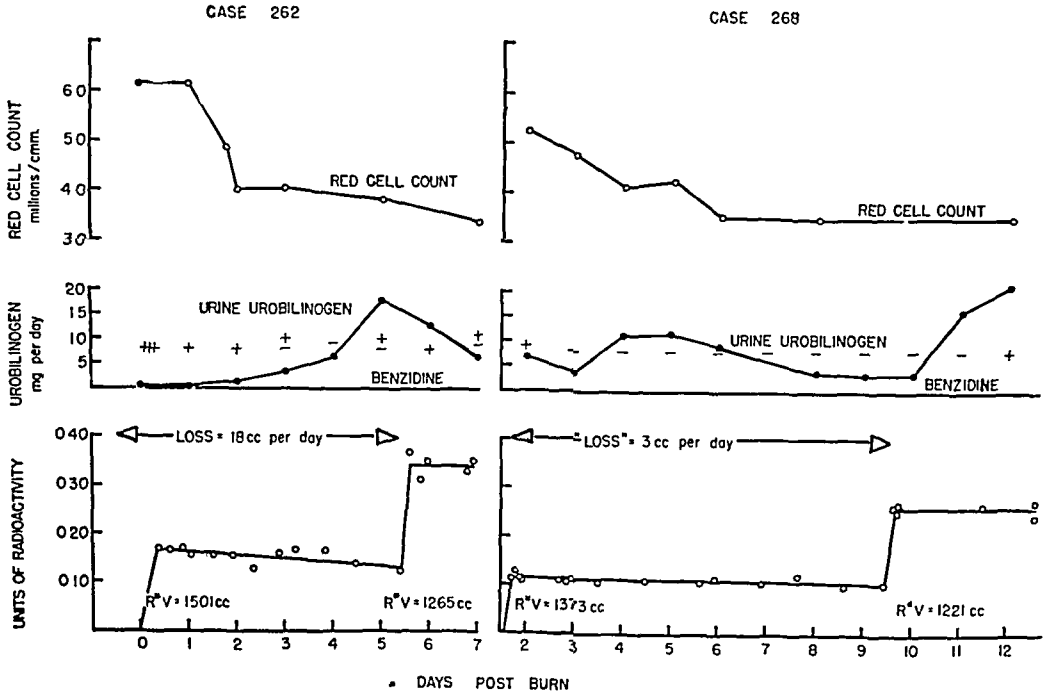



CHART 10.—Cases 262 and 268: Red cell counts, urobilinogen excretion and radioactivity data indicating mild cell destruction in two severely burned, aged patients dying of their injuries (male, age 64, 85 per cent total, 58 per cent third degree; female, age 83, 62 per cent total, 22 per cent third degree).

The rapidly developing peripheral anemia indicated by the fall in red cell count was not accompanied by a comparable decrease in red cell mass and is, therefore, a false anemia. Both patients showed an increase in urobilinogen excretion, Case 262 also showing considerable excretion of benzidine-reacting pigment in the urine. This evidence of red cell destruction was accompanied by a slight fall in red cell mass (R*V) in Case 262. In Case 268 the average loss of 3 cc. of cells per day is within the limits of error of the method.

The radioactivity concentrations in both cases, which resulted from active transfusions given soon after injury, remain approximately constant; the slight fall in Case 262 may be significant, which would indicate active cell regeneration during the period of destruction.

red cell destruction, as indicated in volume measurements, and even jaundice.* The other three, however, all showed evidences of cell destruction which seem to be disproportionally small in relation to their massive and fatal injuries.

* We have seen little clinical jaundice. It is our impression that in a group of sulfanilamide-treated patients clinical jaundice is more frequently encountered than in a series treated with penicillin. This may be traceable to the fact that the blood pigment released in the blood stream by early hemolysis can be metabolised efficiently by the liver if it is not also suffering under the load of an hepatotoxin, such as a sulfonamide.

Case 262.—An elderly man showed a slight rise in urobilinogen excretion but his volume changes showed little evidence of red cell destruction. Multiple determinations of his cell radioactivity after radioactive transfusions showed a slight lowering of activity compatible with slow destruction of the donor cells (Chart 10).

Case 268.—(Chart 10): An aged woman showed no benzidine-positive material in the urine, an unique finding for such an extensive burn (62 per cent total) which was fatal in 13 days. The cell volume data and cell activity data show no departure from normal.

Case 231.—A male, age 36, with a skin burn of 68 per cent, 39 per cent of his total surface being full-thickness, succumbed on his sixth day to the pulmonary effects of the burn and disordered fluid metabolism, with pulmonary edema. An iron build-up curve carried out during his five days of life after the injury showed an essentially normal utilization, a departure from the data recovered from the first two patients of the previous group (Cases 210 and 217). This patient also showed an increase in urobilinogen excretion and a strongly positive benzidine reaction in the urine as evidence of hemolysis.

TABLE XIII

CELL CHARACTERISTICS

| Case | % Burn Total/3° | Day Post-Burn | R.B.C. Millions | Hb. Gm. % | Hematocrit % Cells | M.C.V.* Cμ§ | M.C.H.† γγ ‖ | M.C.H.C.‡ % |
|---|---|---|---|---|---|---|---|---|
| Normal | | | 4.5–5.0 | 16.0 ± 2 | 47 ± 5 | 90–105 | 32–38 | 26–30 |
| 170 | 15/17 | 9 | 3.9 | 11.0 | 41 | 105 | 28 | 26 |
| | | 15 | 4.3 | 12.4 | 44 | 103 | 30 | 28 |
| 260 | 28/12 | 7 | 3.1 | 12.6 | 36 | 115 | 40 | 35 |
| | | 34 | 2.8 | | 34 | 120 | | |
| 135 | 25/15 | 14 | 3.7 | | 37 | 100 | | |
| 149 | 72/38 | 5 | 3.5 | 12.0 | 39 | 111 | 38 | 34 |
| 155 | 41/26 | 1 | 4.3 | 15.1 | 50 | 116 | 35 | 30 |
| | | 16 | 4.1 | 12.6 | 36 | 93 | 32 | 35 |
| | | 30 | 4.0 | 12.6 | 56 | 140 | 32 | 23 |
| | | 40 | 4.8 | 17.5 | 48 | 100 | 35 | 35 |
| | | 55 | 4.3 | 10.6 | 48 | 110 | 25 | 23 |
| 210 | 31/25 | 11 | 2.6 | 8.0 | 25 | 95 | 31 | 33 |
| | | 28 | 3.5 | 11.5 | 38 | 100 | 33 | 33 |
| 217 | 78/45 | 4 | 3.9 | 13.0 | 34 | 87 | 34 | 39 |
| | | 18 | 3.5 | 12.0 | 35 | 101 | 35 | 34 |

Explanation of Table:

* M.C.V. = Mean Corpuscular Volume.

† M.C.H. = Mean Corpuscular Hemoglobin.

‡ M.C.H.C. = Mean Corpuscular Hemoglobin Concentration. The normals are taken from Wintrobe, *et. al.*,[5] except for M.C.V. which is based on our normal R.B.C. of 4.5–5.0 million.

§ Cμ = Cubic micron (.001 mm. = 1μ).

‖ γγ. = One thousandth of a gamma (.000001 mg.).

### 3. OTHER HEMATOLOGIC OBSERVATIONS

The red cell characteristics encountered at various times during the care of patients is shown in Table XIII. These data are representative of the whole group. Some macrocytosis with slight tendency to hyperchromia are the only significant abnormalities.

### COMMENT

Anemia or a decrease in circulating red cell mass is a complication of the deep burn. All of our patients developing a significant anemia, have had burns with full-thickness destruction, usually of 10 per cent or more, of the body surface. Patients with superficial burns of more than 20 per cent of the

body surface may exhibit a false anemia due to hemodilution from an increased plasma volume. In patients with either full-thickness or superficial burns, this false anemia must be differentiated clinically from the true anemia. In the false anemia the treatment depends upon with-holding fluid and allowing renal excretion to keep pace with the resorption of edema fluid. In the true anemia red cells in the form of whole blood transfusions are needed.

In the patient with an extensive full-thickness burn the true and false anemias may coexist. Examination of the patient clinically for stage of edema formation or resorption, of the urine output for diuresis, of the serum for protein dilution, and of the peripheral erythrocyte indices for red cell concentration provides good clues as to the extent of the false anemia. There is no wholly satisfactory substitute, however, for an objective measure of the red cell mass by any one of the several available methods, and such measurements should form a part of the clinical care of an extensively burned patient.

The true anemia of burns develops in three stages; only one or two of the stages may be encountered. The first stage stems from the initial hemolysis connected with the injury and is the least severe of the three. The second stage takes place during the first week or ten days. It may be, in part, related to injury of the red cells, but has other causes, including depression of the bone marrow. The third stage appears in the third or fourth week, has multiple causes, including hemorrhage from the wound, and may persist until the wounds are closed. Between the second and third stages a transitory period of positive red cell balance has been observed in some patients.

From the practical point of view the development of anemia must be constantly suspected in severely burned patients, its extent accurately measured and the red cell deficit met with whole blood transfusions. At the peak of destruction in the second and third stages as much as 500 cc. of blood (250 cc. of cells) may be required each day. In addition, the blood lost in grafting must be replaced. If only grafts are cut, but 100 to 150 cc. may be lost. If excision of the wound is to be carried out before grafting, preparation should be made to replace much larger quantities. Bleeding from excision of recently burned, freshly edematous wounds is limited to a relatively few large vessels, while that from older, more inflamed than edematous wounds may be profuse from numerous small vessels. As much as 1,750 cc. of whole blood has been lost during the excision of extensive, inflamed wounds.

The recent suggestion of Moyer and Coller[14] that whole blood rather than plasma be employed to maintain circulating blood volume after severe burns involves consideration of *Rh* typing, the effect of high hematocrit on blood viscosity and cardiac output, and other questions which are beyond the repair of anemia. The amounts of red cells employed in such treatment far exceed the requirements imposed by the burn anemia, and any results claimed for such therapy cast little light on the extent of this anemia.

Of the factors which may participate in producing the red cell loss in the three clinical stages, the following deserve mention:

1. *Early Hemolysis and Cell Fragility:* Our findings corroborate the pres-

ence of early severe hemolysis in most (but not all) deeply burned patients. The total mass of cells involved in this initial hemolysis does not exceed 10 per cent of the red cell mass. We have no evidence that the increased fragility is due to the heat and not to some other disturbance, for example, in fluid distribution or enzyme activity, which continues to operate for some time after injury.

2. *Blood Destruction by Un-neutralized Plasma Antibodies:* In spite of the theoretic possibility, we have no convincing evidence that un-neutralized plasma antibodies played a rôle in cell destruction in any of the patients included in the present study.

3. *Blood Loss through an Open Wound:* As the burned tissue sloughs away, an open wound is produced which may cover a large area of the patient's body surface. It is clear that any operative procedure, however minor, produces red cell losses from this large surface. It is not so obvious, however, to what extent red cells may leak from this wound into the dressing, there to be digested by bacteria and the hemoglobin converted into a metabolic end-product which removes its color, obscuring the extent of the cryptic hemorrhage.

4. *Infection:* All of our patients showing hidden progressive disappearance of red cells had large open infected wounds. Contamination and subsequent infection is truly inevitable in any deep burn, even with the massive use of penicillin and other agents directed at the infecting micro-organisms.[15] Yet not all of the patients with extensive infected wounds developed anemia. No difference in the types of infecting organisms was noted in those patients developing anemia from those with none.

Infection is doubtless important but until a third degree burn of considerable extent can be maintained without infection by the use of some, as yet unknown, antibacterial agent, it is impossible to separate the factors of iron deposition in the inflammatory barrier and infectious toxemia from the rôle played by a slow-leaking hemorrhage from the large open wound.

5. *Disordered Iron Metabolism and Depressed Marrow Function:* The impaired elaboration of radioactive iron into the hemoglobin of circulating red cells of our patients points to disorder of iron metabolism and depressed bone marrow function as an important factor in the anemia of burns. (This statement is made in spite of the fact that in one patient, later dying of his injuries, a normal utilization was observed.) The low reticulocyte counts generally encountered in our patients and the occasional macrocytosis confirm a depressed marrow activity.

In addition to the mechanism studied by Wintrobe, there are in burned patients other possible causes for disorder of iron metabolism and hemoglobin synthesis. Gastro-intestinal tract function is grossly disturbed. Edema, ulceration, gastritis, all may play a rôle. Liver function may be altered. These factors might lessen iron absorption and hemoglobin synthesis. The impaired utilization of radioactive iron of our patients could not have been due to impaired absorption, however, since the iron was injected intravenously.

6. *The Alarm Reaction:* It is impossible at present to do more than speculate on the importance of the alarm reaction in red cell destruction and bone

marrow depression. Prolonged negative nitrogen balance with transient negative potassium balance has been found in all but one of our cases.[16] If this is an outward manifestation of cell breakdown and the release into extracellular fluid of substances normally intracellular, it is conceivable that the red cells may partake of the process, or perhaps the nucleated erythrocyte precursors in the marrow which more closely resemble other body cells in their vital processes. Another possible explanation is that protein synthesis is blocked; the formation of globin may be retarded, hindering hemoglobin production.

That the alarm reaction or adaptation syndrome[17] is in some manner implicated in the progressive anemia is suggested by the observations that the one patient not showing a negative nitrogen balance did not develop an anemia, and by the rapid increase in cell disappearance following operation (Case 210). Operation is a well-known stimulus of the alarm reaction.

7. *Multiple closely placed transfusions* were occasionally found to be disappointing in restoring red cell volume. On the other hand, no evidence was found to support the contention that transfusions inhibit marrow activity. Undoubtedly the gradual replacement of losses as they occur is more economical of blood as well as more physiologic. Delay in blood replacement is followed by substitution of extracellular fluid for the lost red cell mass, with restoration of total blood volume and a low peripheral red cell concentration. Delayed replacement produces an expanded blood volume which results in an increased cardiovascular load and, possibly, compensatory destruction of a portion of the infused cells.

## SUMMARY

An anemia of varying severity may be present in burned patients. If not repaired, it will retard healing, prolong hospitalization and jeopardize the healing of skin grafts. This anemia has been investigated by serial studies of the red cell mass and bone marrow activity, employing a radioactive isotope of iron and by measurements of pigment excretion.

The anemia is found only in patients with full-thickness burns; it may, in rare cases, surprise one by its absence, even during the acute phase in patients with fatal burns.

True reductions in red cell mass must be distinguished from the false anemia of hemodilution encountered early in the patient's course. The therapy of each differs.

Multiple influences including hemolysis, cryptic wound hemorrhage, iron deviation, gastro-intestinal absorption, infection and marrow depression enter into the etiology of the anemia.

Its anticipation and early replacement is far preferable to late recognition and delayed transfusion.

While clinical observation may provide the astute surgeon with many clues as to the state of the red cell mass, and may help to distinguish true anemia from false (hemodilution) anemia, there is no adequate substitute in the clinical care of a severely burned patient, for serial objective measurements of the red cell volume.

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# ASCORBIC ACID, RIBOFLAVIN, THIAMIN, AND NICOTINIC ACID IN RELATION TO SEVERE INJURY, HEMORRHAGE, AND INFECTION IN THE HUMAN*

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CAREFUL STUDIES of ascorbic acid and of vitamin K in relation to surgical conditions have been reported in numerous publications during the last few years. Few similar studies of other vitamins have been made. In the meantime, all known vitamins are being used in the care of surgical patients with increasing frequency and in increasing doses. Recent work in the laboratory has shown that many vitamins play much more fundamental rôles in the animal organism than merely preventing or curing the well-known syndromes of scurvy, beri-beri, pellagra, or hypoprothrombinemia. For instance, thiamin and nicotinic acid both play fundamental rôles in the enzyme systems that control the metabolism of carbohydrates. Riboflavin is also important for the carbohydrate metabolism and, in addition, has a function associated with amino-acid metabolism. Ascorbic acid is said to have a fundamental rôle in the formation of adrenocortical hormone. These functions indicate that these four vitamins play important rôles in connection with recovery from shock, injury, and acute infections, since disturbances in the metabolism of carbohydrate, protein, and of adrenocortical hormones are caused by these conditions. Thus, Govier[1] has found the mortality of normal dogs exposed to a standardized type of hemorrhagic shock was reduced when thiamin was given in large doses before or after bleeding. In addition, dogs deficient in thiamin were particularly susceptible to death from hemorrhagic shock. Sayers, *et al.*[2] have found that there is a sudden fall in the ascorbic acid content and a slower fall in cholesterol content of the adrenal glands in hemorrhage and in hemorrhagic shock in rats and guinea-pigs. Uzbekov,[3] and Clark and Rossiter,[4] earlier, had found decreases

* From the Burn Assignment of the Surgical Services, the Thorndike Memorial Laboratory and the Second and Fourth Medical Services (Harvard) of the Boston City Hospital, the Departments of Surgery and of Medicine of the Harvard Medical School, and the Fatigue Laboratory of the Harvard Business School.

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in the ascorbic acid content of the adrenal cortex in burned guinea-pigs and rabbits, respectively.

Andreae, and his associates,[5] have studied the excretion of riboflavin in 23 cases of burns and injuries. It is not stated whether shock was encountered in any instance. This short preliminary report is quoted in full because of its importance.

"The 24-hour urinary excretion of riboflavin was followed in 23 patients who had suffered fractures and burn injuries and whose daily intake level of this vitamin was kept constant at 5.0 mg. by supplementation with crystalline riboflavin. Whereas about one-half of the ingested riboflavin is retained at this intake level in health, patients with acute injuries characteristically showed a marked retention during the initial three to five days after injury. This state was followed by a period of similar duration when there occurred an increased riboflavin loss as shown by the excretion rate. After about ten days following the injury, the riboflavin balance returned to normal. This would suggest that the vitamin retained during the first period was not utilized or destroyed, but was stored in some way and subsequently released. Observations made on these patients during convalescence demonstrated a retention of nitrogen. This correlation was statistically analyzed and found to be highly significant so that for each gram of nitrogen retained 0.30 mg. of riboflavin was retained over the normal base line."

The present study is concerned with the alterations in the blood level of ascorbic acid, and in the urinary excretion of ascorbic acid, thiamin, riboflavin, and of n-methyl-nicotinamide, in patients with severe injury, hemorrhage, or infection.

## METHODS

The patients studied were cared for by the members of the "Burn Assignment" in a Metabolic Ward which was supplied with special nurses. The dietary calculations were made by a research dietitian. All hematologic and routine chemical determinations were by methods previously published from the Thorndike Memorial Laboratory.[6] Plasma ascorbic acid determinations were by the method of Mindlin and Butler.[7] The determinations of vitamin outputs were made in the Harvard Fatigue Laboratory using the field methods[8] developed there. These tests were made on timed morning specimens collected at least 14 hours subsequent to any vitamin administration. Vitamin supplements were given orally in the form of ascorbic acid tablets, and of "Multicebrin" capsules. These contain in each capsule: thiamin chloride, mg. 3.0; riboflavin, mg. 3.0; pyridoxine hydrochloride, mg. 1.5; pantothenic acid, mg. 5.0; nicotinamide, mg. 25; ascorbic acid, mg. 75; distilled natural tocopherols, mg. 10; vitamin A, 5,000 U.S.P. units; and vitamin D, 1,000 U.S.P. units. Vitamins were given intravenously in the form of single or multiple vitamin preparations. Saturation tests of vitamins were made as follows: The test doses were given after the collection of a fasting specimen of blood and a fasting hour specimen of urine. Specimens of blood and of urine were then collected at intervals of

one-half, one, two, three, and four hours. Two different test doses were used. One, named a "high test" contained not less than: ascorbic acid, one gram, thiamin chloride, 20 mg., riboflavin, 12 mg., and nicotinamide, 450 mg. The other, the "low test" contained ascorbic acid, 250 mg.; thiamin chloride, 5 mg.; riboflavin, 3 mg.; and nicotinamide, 50 mg. These "low" saturation tests have been used previously in studies of soldiers in all parts of the world.[8] Both "high" and "low" saturation tests have been studied on healthy laboratory personnel at the Boston City Hospital and the findings of these studies will be published shortly.[9]

Table I lists the patients with their diagnosis and the outcome of their treatment.

TABLE I

PATIENTS' DIAGNOSES AND OUTCOME OF TREATMENT

| Case No. | Patient | Age | Sex | Shock | Diagnosis |
|---|---|---|---|---|---|
| 1. | P. D. | 24 | M | 0 | Bullet wounds of jaw, neck, and abdomen with fractured jaw, perforated trachea, and perforated hepatic flexure. Operation—Death—Autopsy |
| 2. | W. B. | 33 | M | + | Bilateral crush injuries both lower legs. Operation—Recovery |
| 3. | P. J. | 15 | M | 0 | Bullet wounds of abdomen and chest, with lacerations of liver, perforated duodenum, ruptured right kidney, and hemopneumothorax. Operation—Death—Autopsy |
| 4. | S. A. | 58 | M | + | Traumatic rupture right kidney, head injury, compound fracture both bones right lower leg. Operation—Recovery |
| 5. | K. R. | 56 | M | + | Massive hematemesis, ? etiology. Operation—Recovery |
| 6. | J. B. | 46 | M | + | Perforated gastric ulcer, peritonitis. No operation—Death—Autopsy |

## CASE REPORTS

CASE 1.—P. D., a 24-year-old white male, with a noncontributory past history, was admitted shortly after receiving bullet wounds of the jaw and abdomen. Examination on entry revealed a well-developed and well-nourished man. Blood pressure 115/80; pulse 132 of good quality; respirations 18. There was a small bullet hole on the right side of the lower jaw through which there was a fair amount of blood oozing. In addition, the patient was coughing up moderate quantities of blood. The lung fields were clear and resonant. Just above the right posterior iliac crest, about two inches from the midline, was another small bullet hole. Anteriorly, there was a small hematoma just to the left of the midline below the costal margin. The abdominal wall was rigid, and peristalsis was absent.

Fourteen hundred cubic centimeters of blood, 1,650 cc. of saline, and 1,000 cc. of 5 per cent glucose in water were administered intravenously in the first four hours after entry. The blood pressure and pulse remained good. At the end of this time, operation was performed.

Abdominal exploration revealed that the hepatic flexure had been perforated posteriorly and anteriorly. Resection of the damaged bowel was carried out and a primary end-to-end anastomosis made. The bullet was removed from the anterior abdominal wall. Exploration of the neck revealed that the second bullet had lodged in the right posterior lateral aspect of the larynx. It was removed and the resulting tracheal fistula packed with gauze. During the operative procedure, the patient was given 500 cc. of blood and 500 cc. of saline, and the blood pressure and pulse remained good. The urine output was satisfactory. Postoperatively, slight oozing of blood through the mouth continued and constant pharyngeal suction was carried out. The temperature varied from 100° to 102° F. rectally; the blood pressure and pulse re-

mained good, but there was sudden respiratory distress and asphyxia five hours postoperatively. Postmortem examination revealed the cause of death to have been aspiration of blood.

No vitamins were given at any time. The plasma ascorbic acid concentration at one and at three hours after entry was zero. At seven hours after entry it was 0.3 mg./100 cc. of plasma. Hourly excretion rates of the vitamins at 2.5 and 4.5 hours after entry were as follows: thiamin 0.3 and 10 micrograms per hour; riboflavin, 26 and 17 micrograms per hour; and the n-methyl-nicotinamide, 0.35 and 0.68 milligrams per hour.

COMMENT: A previously well-developed and well-nourished healthy male with major injuries but with no shock and with a good urine output. The plasma ascorbic acid was zero on two occasions prior to operation, but rose slightly during recovery from operation. The first determination of thiamin output was low but the second determination of thiamin and both determinations of riboflavin and of the n-methyl-nicotinamide were normal.

CASE 2.—W. B., a 33-year-old white male, with a noncontributory past history was admitted at 6 P.M., shortly after receiving crush injuries to both legs when he fell under a street car when intoxicated. Examination revealed a well-developed and well-nourished man, semiconscious. His skin was pale and cold, his blood pressure 70/50, pulse of fair quality. Both lower legs were crushed just below the knees and, in addition, there was a simple intracapsular fracture of the neck of the left femur. Leather belts had been applied as tourniquets at the scene of the accident. These were replaced by rubber tourniquets. He was given mg. 30 of morphine and an intravenous of saline, plasma, and of whole blood started. The blood pressure rose to 90/50 in 30 minutes and to 110/50 in the next one and one-half hours. His pulse was 100 at this time and of good quality. The urine output was good.

During the first six hours he was given a total of 1,000 cc. of plasma, 2,000 cc. of blood, and 2,000 cc. of saline. At this time, under cyclopropane anesthesia, bilateral, low thigh, guillotine amputations were done. The wounds were left open and dry pressure dressings applied. A Kirschner wire was inserted through the lower end of the left femur to serve as a means of applying traction to the fractured left femoral neck. During the operation he was given 1,000 cc. of additional blood. His blood pressure remained good until just after the operation, when it fell for a brief period to 70/50, at the time of a mild hemolytic transfusion reaction. Thereafter there were no further periods of shock. Penicillin, 20,000 units every two hours intramuscularly, was started on entry and continued for 15 days. The temperature which during the first few days rose as high as 102° F. rectally, became normal by the seventh day and remained normal thereafter. The wounds were secondarily revised and closed on the 17th and 28th days. During the first five days he was fed almost entirely intravenously with Amigen* and glucose in quantities sufficient to give him 20 Gm. of nitrogen and 3,000–4,000 calories daily. Subsequently he took food well by mouth. This diet contained approximately the same amounts of nitrogen and calories as given previously. The nitrogen output varied between 17 and 42 grams daily. The nitrogen balance and vitamin data are given in Charts 1 and 2.

COMMENT: The ascorbic acid concentration on three occasions during the first 12 hours was zero. At 16 hours, without any ascorbic acid having been given, the plasma level had risen to 0.3 mg. per 100 cc. At that time a "high" saturation test was performed. (See Chart 2.) The plasma response to this was lower than is seen in normal individuals. The excretion

*The Amigen was kindly supplied by the Mead-Johnson Corporation.

was also low, being less than 50 mg. The next day this test was repeated. The plasma curve was almost identical, but nearly 300 mg. was excreted. This is still below the usual excretion of a fully saturated individual. The

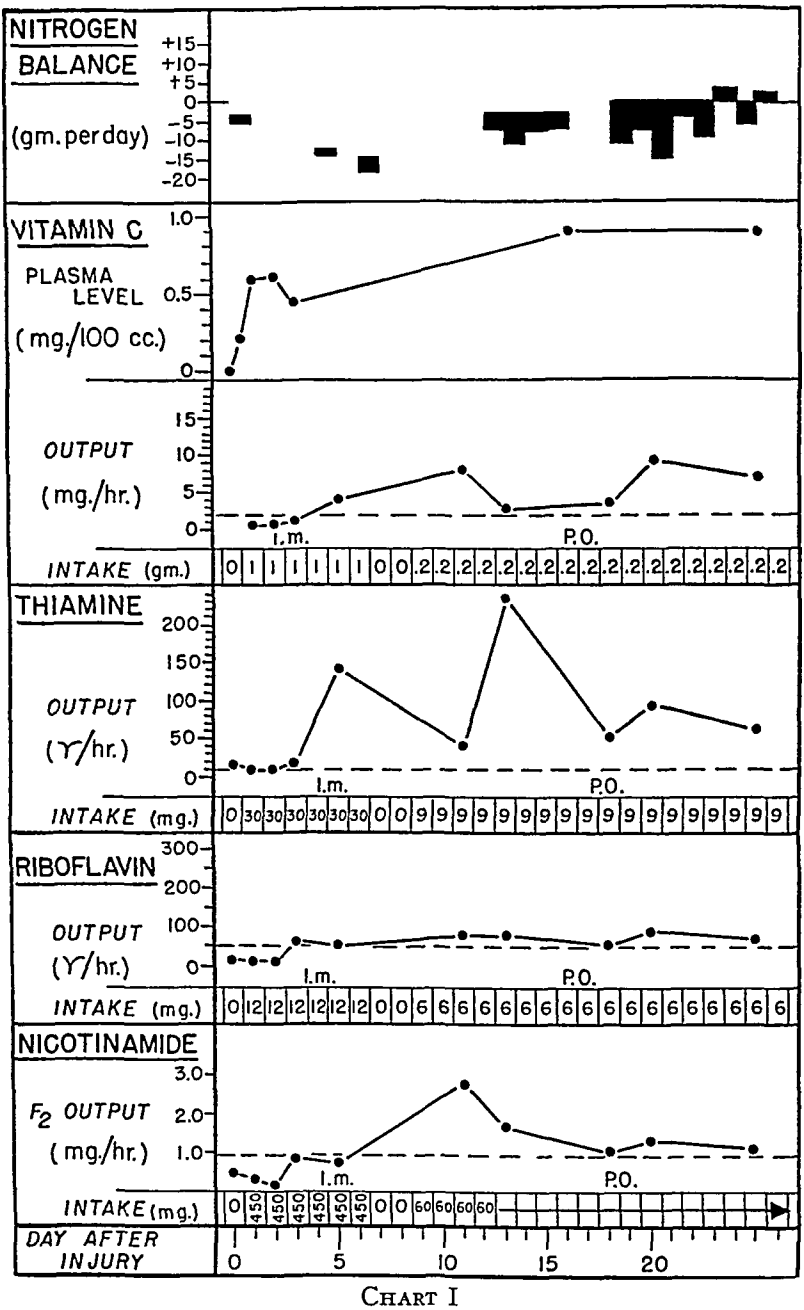



CHART I

The dotted lines indicate the *average* output of normal men on normal diets who are taking no supplementary vitamins.

fasting hour excretions of the three "B" vitamins and ascorbic acid were at low levels immediately after injury and, what is important, remained at these low levels for five days despite large doses given daily, as shown by Chart 1.

CASE 3.—P. J., a 15-year-old healthy high school boy, was admitted shortly after receiving a bullet wound of the abdomen. Examination revealed him to be well-developed and well-nourished. He was somewhat drowsy but fully conscious and rational. Blood pressure 90/40. His chest was clear and resonant throughout, and his abdomen was spastic, with absent peristalsis. Just above the umbilicus in the midline was the entrance wound of a bullet and posteriorly over the region of the right kidney was the exit wound. Both wounds were bleeding slowly.

He was given mg. 10 of morphine, and intravenous glucose in saline was started. After 400 cc. had been given in a period of a half hour, the blood pressure rose to 140/78. His pulse at this time was 108 and his respirations 20. In the next 1.5 hours he was given 500 cc. of blood, following which, under spinal anesthesia supplemented by cyclopropane, operation was carried out. It was found that the left lobe of the

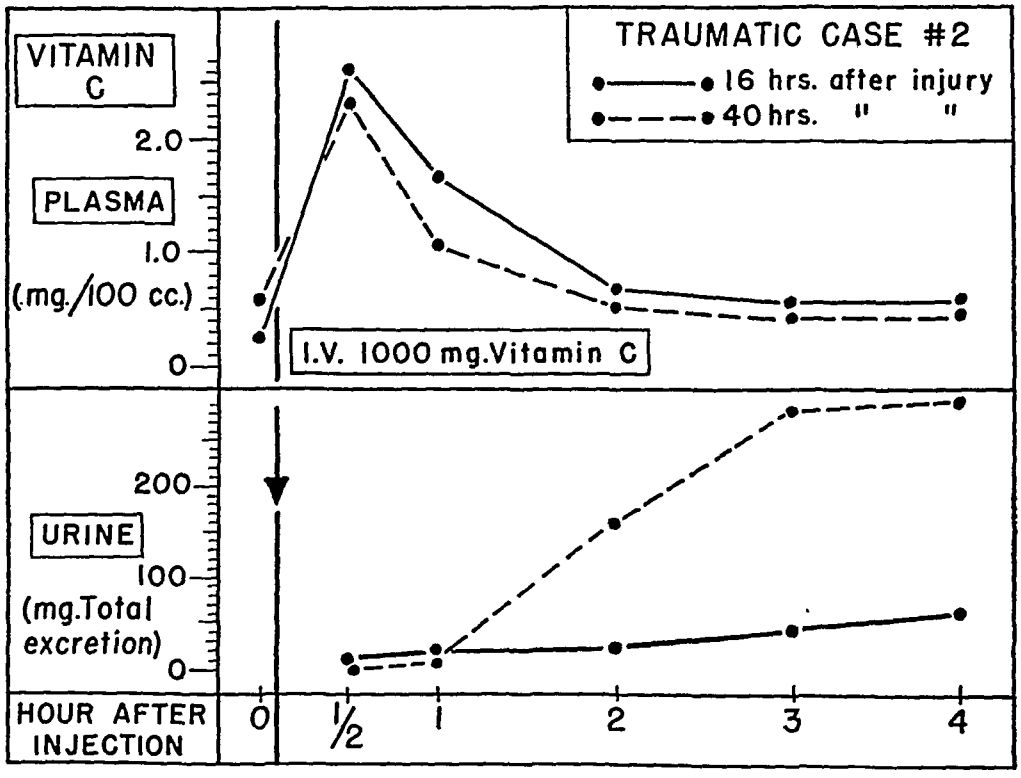



CHART II

Saturation test—Ascorbic Acid Intravenously

liver, the duodenum, the right lobe of the liver, the right kidney, and the right pleural cavity had all been perforated by the bullet. Crushed liver tissue was removed, the two perforations in the duodenum repaired, and the kidney removed. Drains were inserted down to the kidney bed and to the liver wound. The wound of entrance was excised and packed open with gauze. The wound of exit was also excised and was found to connect with the right pleural cavity. There was about one pint of blood in the pleural cavity and during exploration of the wound air was sucked in during inspiration. A gauze pack was inserted to control the aspiration of air. During the operation, the patient was given additional blood and saline. The blood pressure and pulse remained good, and thereafter there was no fall in blood pressure.

Postoperatively, he was given 25,000 units of penicillin every two hours for the first ten days. Five grams of sulfadiazine were given by clysis daily for the first three days and orally thereafter. Gastric drainage was instituted immediately after operation, and he was given 150 grams of protein hydrolysate and sufficient glucose intravenously to bring his caloric intake to 3,000 calories. Vitamins were started on the first postoperative day, as described below.

His postoperative course was satisfactory for the first week. He then began to run an afternoon fever of 102° F., but had no specific localizing signs. His urine output was three liters, or more, per day. On the 10th postoperative day, under cyclopropane anesthesia, the pack from the epigastric wound was removed, as was the drain from the liver and one of the drains to the kidney region. Culture of the wounds revealed *B. pyocyaneous.* The pack was taken out of the wound of exit, which was found to still connect with the pleural cavity. Consequently, a gauze pack was reinserted and the patient left the operating room in good condition. About ten hours after the dressing change the patient appeared considerably sicker and was markedly dyspneic. Examination revealed signs consistent with a pneumothorax in the right chest. The abdomen was soft and not tender. Roentgenograms confirmed the diagnosis of pneumothorax. Five hundred cubic centimeters of air were removed from

TABLE II

CASE 3: P. J.—BULLET WOUNDS OF LIVER, DUODENUM, AND KIDNEY

| Days | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | | 103° | 102° | 102° | 101° | 104° | 101° | 102° | 101° | 105° | 102° | 105° | 105° | 1 5° |
| Caloric intake | 550 | 2950 | 2900 | 3050 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 2500 | 1100 | 2250 |
| Nitrogen intake (grams) | 7 | 23 | 26 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 19 | 0 | 3 |
| Nitrogen output (grams) | | 15 | 25 | 25 | 27 | 22 | 24 | 19 | 25 | 22 | 39 | 16 | 37 | 9 |
| Plasma protein (grams/100 cc.) | 5.7 | 4.7 | | 5.6 | | | | | | | | 6.8 | | |
| Plasma ascorbic acid (mg./100 cc.) | 0.6 | 0.6 | | 0.6 | | 0.5 | | | 0.8 | | 1.1 | | | |
| Urine ascorbic acid (mg. per hour) | | 6 | | 4 | | 17 | | 24 | | | 13 | | | |
| Urine thiamin (micrograms per hour) | | 28 | | 35 | | 225 | | 510 | | | 200 | | | |
| Urine riboflavin (micrograms per hour) | | 105 | | 17 | | 57 | | 64 | | | 68 | | | |
| Urine n-methyl-nicotinamide (micrograms per hour) | | 0.3 | | 0.6 | | 3.2 | | 2.6 | | | 1.4 | | | |

Vitamins were administered intravenously in the following daily doses from the 1st to the 13th day: Ascorbic acid, G 1.0; thiamin mg. 30; riboflavin, mg. 12; and nicotinamide, mg. 450.

the right chest, without significant effect on the dyspnea. His temperature had risen to 105°F. rectally. Penicillin which had been discontinued following the dressing, was resumed, and, in addition, sulfamerizine was begun, the sulfadiazine also having been omitted at the dressing change. Roentgenograms the following morning revealed the pneumothorax to be less and the lung fields to be clear except for some atelectasis of the right lower lobe. There was neither cyanosis nor dyspnea. The temperature continued high despite repeated alcohol sponges. Two lumbar punctures were negative. He gradually became weaker and died on the 14th day. Autopsy revealed no definite cause of death. The nutritional and vitamin data are given in Tables II and III.

COMMENT: This boy had a severe injury but was in excellent muscular training and nutritional condition. He did not go into shock at any time. Early, his ascorbic acid concentration in the plasma remained relatively high, being 0.6 mg. per 100 cc. of plasma on two occasions prior to any vitamin supplementation. He was given one gram of ascorbic acid; thiamin

30 mg.; riboflavin 12 mg.; and nicotinamide 450 mg. daily beginning on the first hospital day. On the first, third, seventh, and eighth days the vitamins were given in rapid injections for "high" saturation tests. On all other days they were given in a slow intravenous drip. The plasma ascorbic acid concentration remained between 0.5 and 1.1. The plasma levels of ascorbic acid in the first two tests were low but in the fourth test were normal. The four-hour urine excretions of ascorbic acid, thiamin, and riboflavin during the saturation tests were low on the third day, normal on the seventh day. The excretion of n-methyl-nicotinamide was normal on both occasions.

The "fasting hourly" excretions of ascorbic acid, thiamin, and n-methyl-nicotinamide were much lower on the first and third postoperative days than on the fifth and subsequent days. In the case of riboflavin, the first day excretion was higher than that on subsequent days.

TABLE III

CASE 3: P. J.—"HIGH" SATURATION TESTS

| Days | Plasma Ascorbic Acid Milligrams Per 100 Cc. Hours | | | | | Urine—Output in Four Hours | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fasting | 0.5 | 1 | 2 | 4 | Ascorbic Acid (Milligrams) | Thiamin (Milligrams) | Riboflavin (Milligrams) | N-methyl-nicotinamide (Milligrams) |
| 1. | 0.6 | 1.9 | 1.7 | 1.5 | 1.0 | | | | |
| 3. | 0.6 | 1.4 | 1.3 | 1.3 | 0.6 | 108 | 4.0 | 0.6 | 23 |
| 7. | | | | | | 484 | 17 | 10 | 56 |
| 8. | 0.8 | 3.1 | 2.9 | 2.7 | | | | | |

Saturation test doses: Ascorbic acid, G. 1.0; thiamin, mg. 30; riboflavin, mg. 12; and nicotinamide, mg. 450.

CASE 4.—S. A., a 58-year-old laborer, previously well, except for chronic bronchitis, was seen three hours after having been struck by an automobile. Examination on admission revealed a well-developed, well-nourished man with a compound fracture of both bones of the right lower leg and a laceration over the right eye. There were no external bruises elsewhere, and examination was otherwise negative. Blood pressure 80/50, pulse 90. During the next five hours he was given 900 cc. of plasma, 1,500 cc. of whole blood, 900 cc. of saline, and 50 grams of glucose. His blood pressure varied between 70/50 and 110/60, with his pulse remaining about 90. His abdomen, which had previously been soft, gradually became generally spastic and tender. Catheterization revealed grossly bloody urine. A spinal puncture revealed bloody fluid but a normal pressure of 160 mm.

Under spinal anesthesia, supplemented with cyclopropane, gas and ether, celiotomy was performed. There was about 200 cc. of blood in the peritoneal cavity but no injury to any interperitoneal organs. The blood had dissected up from the right retroperitoneal area where there was a large hematoma. The celiotomy wound was closed and a laparotomy exposed the right kidney, which was found to be ruptured completely across the pelvis. It was removed. The wound was packed and partially closed. During the operation the patient was given 1,000 cc. of whole blood; 1,200 cc. of saline and bicarbonate by clysis; and 50 grams of glucose intravenously. His

blood pressure, which was between 70/40 and 90/60 during the operation, rose immediately after the kidney was removed to 120/84. Thereafter there were no periods of shock.

The wound of the right lower leg was then irrigated and débrided. Kirschner wires were passed above and below the fracture line of the tibia and a plaster encasement was applied. The wound was not closed, even in part.

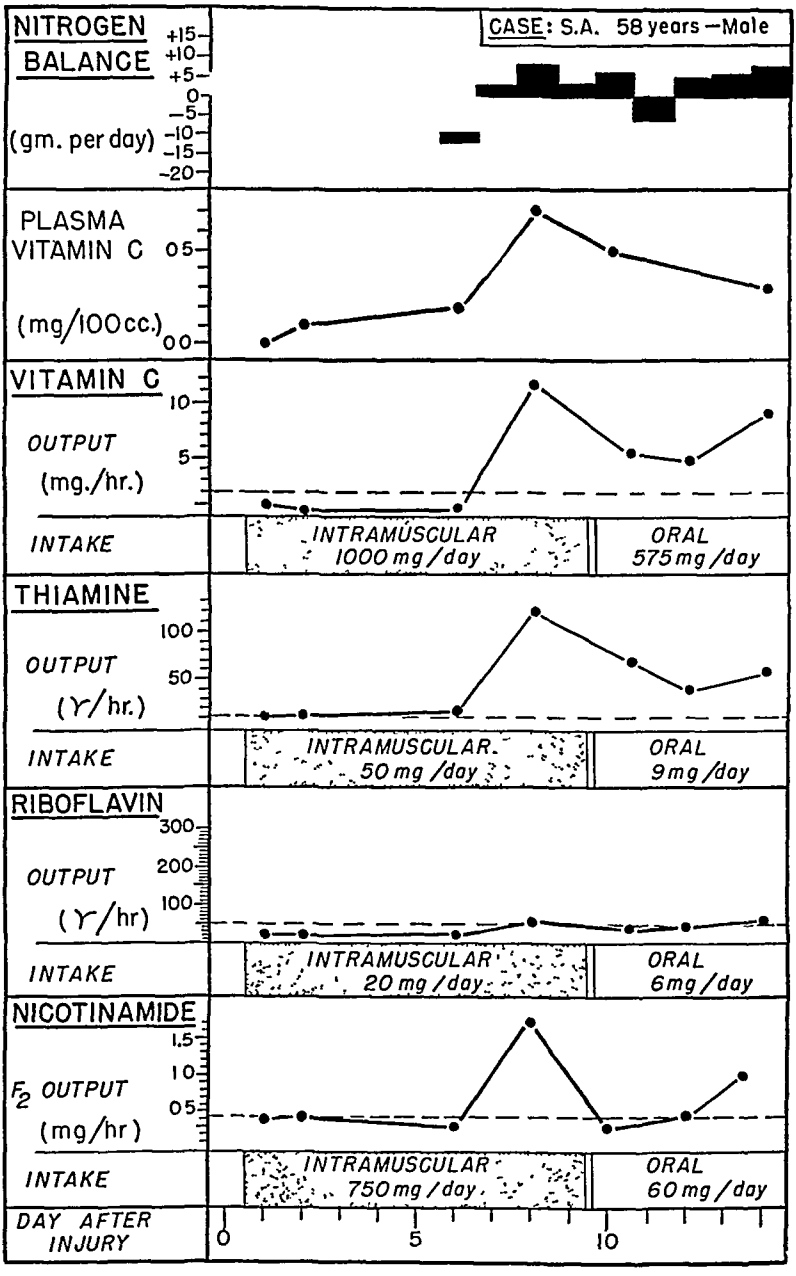



CHART III

Two hours postoperatively, 12 hours after injury, his temperature had risen to 106°F. rectally. Vigorous cold alcohol sponges were administered, and the temperature fell to 102.6° F. in the next one and one-half hours. At this time, a neurologic examination was negative. A second lumbar puncture revealed that the pressure had risen

to 300 mm. Repeated therapeutic lumbar punctures were performed during the next few days. After the sixth day the spinal fluid pressure and spinal fluid were normal.

Eighteen hours postoperatively, he became moderately dyspneic and cyanotic. A chest roentgenogram revealed diffuse mottling of the upper left lobe. Penicillin, 20,000 units, was given intravenously every two hours, and oxygen was administered by a tent. Within 36 hours he had improved, the dyspnea had disappeared, and only slight cyanosis remained. A chest film ten days later revealed the lung fields to be clear.

The clinical course after the second day was uncomplicated except for minimal infection of the kidney wound. The temperature ranged between 101° and 102°F. rectally until the 12th day, and after the 14th day was normal. Penicillin was discontinued on the 15th day. He was allowed to get out of bed daily after the seventh day, and felt very well. The hemoglobin which had been 90 per cent on entry fell gradually to 67 per cent by the eighth day. Two thousand cubic centimeters of whole blood was given in the next six days, the hemoglobin rising to 95 per cent.

During the first week he was given nourishment for the most part by the intravenous route. This consisted of plasma and glucose on the first day with Amigen and glucose for the next six days. The caloric intake ranged between 1,500 and 1,700 calories, with an average of 1,550. The nitrogen intake ranged from 14 to 17 grams, with an average of 15. The nitrogen output in the urine was 10 grams the first day, 30 grams the second and gradually decreased to 21 grams on the sixth, followed on the seventh day with an output of only 15 grams. There were no stools during this period. In the second week, oral feeding only was used, with an intake of from 2,700–4,100 calories, with an average of 3,100. The nitrogen intake ranged from 13 to 25 grams, with an average of 18. The nitrogen output ranged from 12 to 18 grams, with an average of 15.

The serum nonprotein nitrogen which was 50 mg. per 100 cc. on entry, rose to 70 the first day, came down to 60 on the second, and to 30 on the seventh day. The plasma albumin was 3.2 grams per 100 cc. on the first day, 1.35 on the seventh day, and 3.1 on the 16th day. The total plasma protein levels on the same days were 5.3, 5.3, and 6.7. The metabolic and vitamin data are presented on Chart 3.

COMMENT: This relatively old, but muscular laborer had extremely severe injuries, with a long period of shock. The blood level of ascorbic acid and the urinary excretion of all four of his vitamins remained extremely low in comparison to his enormous intakes until the eighth day when they all increased to excretion levels which were normal for his intake.

CASE 5.—K. R., a 56-year-old white male, was admitted because of repeated hematemeses for 24 hours. The day before entry, while at work, he suddenly vomited a cupful of bright red blood. Shortly thereafter he felt some vague abdominal pain, dull in character. The pain began in the midlower abdomen and extended up to the xiphoid; it did not radiate. During the next 24 hours the patient had at least ten episodes of vomiting blood. After the first few he began to feel dizzy, weak, and somewhat sweaty. The abdominal pain disappeared gradually about 18 hours after onset.

Until one year ago the patient was in good health but during the past year he had noticed a gradual weight loss, possibly as much as 25 pounds, and loss of appetite. There has been no nausea, vomiting, abdominal pain, constipation, diarrhea, jaundice, light stools, or dark urine, or melena. He had had varicose veins for many years with occasional edema of the feet.

Physical examination revealed a well-developed man with some evidence of recent weight loss. He was apathetic and sweating. His temperature was 97°F. rectally; pulse 120, and blood pressure 78/65. The pulse was weak and thready and his extremities were cold. Abdominal examination revealed generalized spasm but no

tenderness. The upper border of liver dullness was in the sixth interspace on the right. The lower edge of the liver could not be felt, but by percussion, dullness was present four fingers below the costal margin. Peristalsis was absent. There were no distended veins or venules on the abdomen. No masses could be felt. Rectal examination was negative except for the presence of dark red and black colored fecal material. His skin was clear. There were no telangiectases or jaundice. There were no obvious bleeding points in the mouth or throat. The chest was emphysematous, resonant, with some coarse bronchial râles. The heart was not enlarged, and its sounds were of poor quality. Its rhythm was regular, and there were no murmurs. The extremities were negative except for marked varicosities bilaterally.

Laboratory data on entry revealed a red count of 2.7, hemoglobin of 62 per cent, icterus index 3, white count 12,000, and prothrombin 100 per cent of normal. His N.P.N. was 71 mg. per 100 cc., and his serum protein 4.5 grams per 100 cc. of serum. The stools showed a strongly positive guaiac test and the urine was negative except for moderate traces of albumin.

*Clinical Course:* During the first three hours, the patient was given two liters of blood and 1,800 cc. of intravenous saline. The blood pressure rose to 120/70, the pulse dropped to 84, and the temperature rose to 100.6°F. At this time, under spinal anesthesia supplemented by cyclopropane, a subtotal gastrectomy was done. No definite bleeding point was found. During this procedure the patient received an additional 300 cc. of blood. The pulse remained of good quality, about 80, and the blood pressure rose to 150/80. Postoperatively, the patient was put on gastric suction. The following day he was given intravenous protein hydrolysate and glucose which was continued daily for the next ten days. He was started on water and milk by mouth on the fifth day and a soft diet on the sixth day. The details of his caloric and nitrogen intake, and nitrogen output for the first two weeks are given in Table 4. He was in negative nitrogen balance during the first week, and then in slight positive nitrogen balance on the second week. Nitrogen balance studies were discontinued at this time. The patient lost 12 pounds of weight. The plasma protein concentration was above six.

On the 16th day he developed calf tenderness and a positive Homan's sign bilaterally. Therefore, a bilateral femoral ligation was performed. His temperature rose during the next four or five days to 102° and 103°F. Repeated blood cultures were negative except for one which was reported showing an *alpha* streptococcus. His temperature subsided slowly, but continued to rise to 100°F. each afternoon for about a week. His course thereafter was normal and he was discharged ten days later. The laboratory data are detailed in Tables IV and V and Chart 4.

COMMENT: During the first two weeks he received vitamin supplements only on the first, sixth, and 13th days as test doses for "low" saturation tests. During this time the fasting concentration of ascorbic acid varied between zero and 0.7 mg./100 cc. plasma. The values after "low" saturation tests on the first, sixth, and 13th days were very low, as indicated in Chart 4. The four-hour urine excretion of ascorbic acid during these saturation tests were also very low, particularly on the 13th day when only 13 mg. were excreted. The fasting hourly excretion of ascorbic acid was also low at the end of the second week. During this first two-week period, and in fact, the entire period study, the fasting hourly excretions and the response to tests for thiamin, riboflavin, and n-methyl-nicotinamide were within normal range.

During the third week a supplement of 225 mg. of ascorbic acid, 9 mg.

TABLE IV

CASE 5: K. R. HEMATEMESIS WITH SHOCK.

| Days | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight | | | | | | | 143 | | | | | | | | | 137 | 133 | | | | | | | | | | | 131 | |
| Temperature | 97 | 104 | 103 | 103 | 100 | 100 | 100 | 100 | 103 | 101 | 100 | 101 | 101 | 101 | 100 | 100 | 102 | 103 | 103 | 103 | 102 | 101 | 101 | 100 | 100 | 101 | 100 | 100 | 99 |
| Caloric intake | 700 | 2600 | 1950 | 1900 | 3100 | 2900 | 2800 | 740 | 2350 | 2900 | 2100 | 1600 | | | | | | | | | | | | | | | | | |
| Nitrogen intake (grams) | 11 | 14 | 12 | 12 | 18 | 22 | 10 | 7 | 22 | 26 | 16 | 17 | | | | | | | | | | | | | | | | | |
| Nitrogen output (grams) | 11 | 9 | 18 | 18 | 24 | 23 | 16 | 16 | 23 | 23 | 15 | 16 | | | | | | | | | | | | | | | | | |
| Ascorbic acid intake (grams) | 0 | 250 | 0 | 0 | 0 | 0 | 250 | 0 | 0 | 0 | 0 | 0 | 0 | 250 | 225 | 225 | 225 | 225 | 225 | 225 | 475 | 225 | 500 | 500 | 500 | 500 | 500 | 500 | 5,00 |
| Plasma protein (grams per 100 cc.) | | | | | 6.8 | | | | | | | 6.0 | | | | | | | | | | | | | | | | 7.1 | |
| Plasma ascorbic acid; (milligrams per 100 cc.) | 0.3 | 0.0 | | | | 0.5 | 0.0 | | | | | | 0.8 | 0.0 | | | | | | 0.2 | 0.0 | | | | | | | | 0.8 |
| Ascorbic acid output; (milligrams per hour) | | 1.2 | | 2.1 | | | 1.3 | 2.5 | | | 0.8 | | | 0.7 | 0.4 | | | 1.2 | | 1.3 | 3.1 | 2.1 | | | 2.1 | | | | 4.3 |
| Thiamin intake (milligrams per hour) | | 5 | | | | | 5 | | | | | | | 5 | 9 | 9 | 9 | 9 | 9 | 9 | 14 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Thiamin output (micrograms per hour) | 12 | | 7 | | | | 5 | 8 | | | 4 | | | 8 | 3 | | | 140 | | 43 | 50 | 49 | | | 90 | | | | 39 |
| Riboflavin intake (milligrams per hour) | | 3 | | | | | 3 | | | | | | | 3 | 9 | 9 | 9 | 9 | 9 | 9 | 12 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Riboflavin output (micrograms per hour) | | 40 | | 70 | | | 65 | 1.8 | | | 1.0 | | | 54 | 52 | | | 184 | | 150 | 300 | 85 | | | 250 | | | | 75 |
| Nicotinic acid intake; milligrams per hour) | | 50 | | | | | 50 | | | | | | | 50 | 75 | 75 | 75 | 75 | 75 | 75 | 125 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| N-methyl-nicotinamide output; (milligrams per hour) | | 0.6 | | 0.5 | | | 0.5 | 0.3 | | | 0.2 | | | 0.4 | 0.2 | | | 0.5 | | 0.4 | 1.0 | 0.5 | | | 1.3 | | | | 0.5 |

each of thiamin and riboflavin, and 75 mg. of nicotinamide was given daily by mouth. The plasma ascorbic acid concentration both fasting, and after a "low" test on the 20th day, remained low as did the four-hour urinary excretion after injection of the test done.

CASE 6.—J. B., a 46-year-old white male, with a noncontributory past history, was admitted because of abdominal pain of 24 hours duration. He had been in good health until the day prior to entry, at which time he had sudden severe upper abdominal pain. Soon thereafter the pain reached to both shoulders, and he began vomiting, and vomited repeatedly until entry. There was no hematemesis or melena.

Examination revealed a fairly well-developed and well-nourished man who was dehydrated, apathetic, and in shock. His temperature was 97° F., and his pulse and blood pressure were unobtainable. The abdomen was spastic throughout, peristalsis was absent, and there was marked abdominal distention. The lung fields were clear.

TABLE V

CASE 5: K. R.—"LOW" SATURATION TESTS

| Day | Excretion in Four Hours | | | |
|---|---|---|---|---|
| | Ascorbic Acid (Milligrams) | Thiamin (Milligrams) | Riboflavin (Milligrams) | N-methyl-nicotinamide (Milligrams) |
| 1 | 24 | 0.8 | 0 9 | 7 |
| 6 | 21 | 1.2 | 0.4 | 9 |
| 13 | 13 | 1.3 | 0.9 | 11 |
| 20 | 5o | 1 7 | 1.1 | 8 |

The doses given were: Ascorbic acid, mg. 250; thiamin, mg. 5, riboflavin, mg. 3, and nicotinamide, mg. 50.

On entry, 1,500 cc. of saline were given intravenously within 40 minutes. The blood pressure rose to 100/65 and the pulse became of fairly good quality. An additional 3,000 cc. of saline were given in the next three and one-half hours; the blood pressure remaining between 92/60 and 108/90, and the pulse between 92 and 104. The temperature rose to 100.4°F. Whole blood was then started intravenously, 1,500 cc. being given in the next four hours. Thereafter he received a slow intravenous injection of 4 per cent Amigen and 15 per cent glucose.

Roentgenograms of the abdomen and chest revealed a large amount of free air under the right diaphragm, with some elevation of the right diaphragm and some clouding at the left lung base. Gastric drainage was started on entry. The abdominal distention increased gradually and led to marked impairment of the respiratory movements. An abdominal tap ten hours after entry yielded large amounts of gas and two liters plus of purulent yellowish-green fluid containing many gram-negative mobile rods. The respirations were much easier after the abdominal tap. The patient was placed in an oxygen tent and given penicillin, 20,000 units intravenously every two hours. The patient gradually became weaker, finally comatose, and died 36 hours after entry. The urine output had been low and during the last 24 hours he had intermittent periods of shock. The temperature rose to 103°F. An autopsy revealed an enormous opening in the stomach from a perforated ulcer.

Four hours after entry a saturation test was attempted. He was given ascorbic acid G 1.0, thiamin mg. 30, riboflavin mg. 12, and nicotinamide mg. 450. Unfortunately,

the urine output was negligible so that determination of vitamin outputs could not be made. The ascorbic acid plasma curve is shown in Chart 5.

COMMENT: A previously well, healthy male, with a neglected large perforation of a gastric ulcer, who entered the hospital in extreme shock. Although his blood pressure improved at times during treatment, he never reached a condition that seemed to warrant surgical intervention. His plasma ascorbic acid saturation curve showed a very low response to the test.

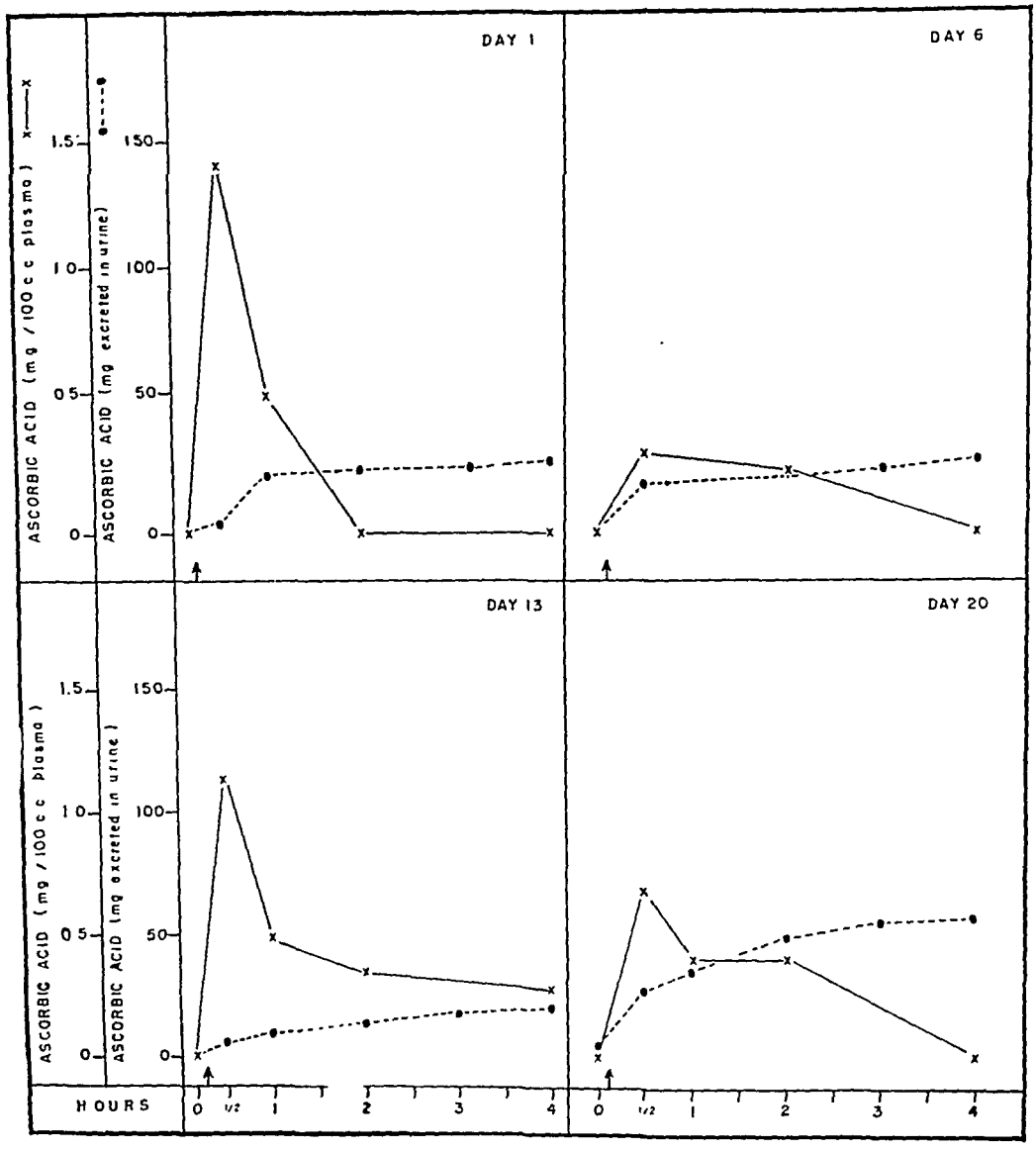



CHART IV

DISCUSSION.—The data presented demonstrate that six patients with severe injuries, hemorrhage, or infection had marked abnormalities in the metabolism of ascorbic acid, thiamin, riboflavin, and nicotinamide. These were evidenced by one or more of the following items: Low concentration of ascorbic acid in the plasma, fasting or after saturation tests, and low excretions of all four vitamins under the same two conditions. The abnormality is most marked when the patient is most sick; that is, when the metabolic

disturbances of the carbohydrates, proteins, and adrenocortical hormone are also most marked.

Theoretically, some or all of the findings might be accounted for by the following possibilities:

1. *Deficiencies before Injury.*—All of these patients had no recognizable signs or symptoms of deficiencies of these vitamins at the time of entry to the hospital. Several may have had less than fully saturated conditions of one or more of them. But the experiment of Crandon, Lund and Dill[10] showed that the plasma level fasting, and following therapy, and the excretion following therapy, rose much more rapidly after actual scurvy had been

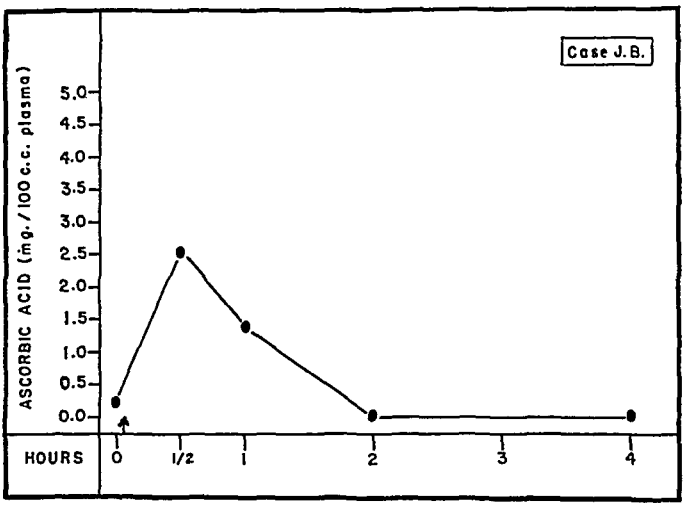



CHART V

treated with the same dose of ascorbic acid than these items rose in Patient 4 in this series. It does not seem possible that preëxisting deficiencies played any rôle in the findings in Patients 1, 2, 3, or 4 in this series, or more than a slight rôle in Cases 5 and 6.

2. *Inadequate Dosage.*—The dosage of vitamins administered varied from no dose to very large doses. Even the patients given the largest doses showed slight excretions during the acute phase of their illnesses but then showed very active excretions as soon as their metabolic disturbances were corrected.

3. *Failure of Absorption.*—Most of the vitamins were given intravenously. When they were given by mouth there were no instances of vomiting or diarrhea during the periods of mouth administration. Therefore, none of the results could have resulted from lack of opportunity for the vitamins to enter the blood.

4. *Excretion in the Sweat.*—That deficiencies might result from losses in the sweat has been postulated. Sargent, Robinson, and Johnson[11] have recently shown that sweating cannot cause important losses of these vitamins.

5. *Secretion in Exudates.*—Vitamins might be lost into exudates. Only one of the six patients (Case 6) had any important exudates.

6. *Storage.*—As noted in the introduction, Andreae, and his associates, interpret the evidence from their study of riboflavin excretion after injury as showing that riboflavin is stored early and excreted later. There is no data in the present study that confirms this finding for riboflavin. However, this difference in findings may be the result of differences in the technic of study. Andreae used the balance technic rather than the "fasting hour." At the same time, there is no evidence that any of the other vitamins react in this way.

7. *Destruction.*—It is possible that vitamins may be destroyed without performing any useful function during their destruction. This study contributes no evidence for or against such a postulate.

8. *Increased Utilization.*—Holt[12] has shown increased utilization of thiamin in conditions of stress such as increased basal metabolism and fever. As mentioned above, other stresses associated with acute hemorrhage or other medical or surgical illness, are followed by markedly increased turnover of protein and carbohydrate. Since the vitamins of the B group discussed here are intimately concerned with the metabolism of these substances, it is likely that the demand for, and utilization of them is increased. Similarly, it has been postulated that the demand for and utilization of ascorbic acid is increased due to its relation to the adrenocortical hormones.[2] The findings in the present study can best be explained by increased utilization.

It may be asked whether there is evidence in this study that administration of these vitamins was beneficial to these patients. Such evidence could only result from the study of large numbers of cases with comparable injuries or disease. Even the patients whose recovery was particularly gratifying (Cases 2, 4, and for the first eight days Case 3) and who were given large doses of vitamins had so many other powerful therapeutic agents used that we can have no opinion in answer to this question. On the other hand, the experimental work quoted above, and the demonstration of actual or apparent deficiency of ascorbic acid in the plasma and of all four vitamins in the urine under the conditions of the study, indicate that such treatment is reasonable as an attempt to aid the organism to achieve homeostasis.

If one accepts the possibility that these vitamins are useful in these conditions, do these results indicate any particular doses for such cases? It would seem reasonable to use doses of not less than one gram of ascorbic acid, 50 mg. of thiamin, 50 mg. or riboflavin, and 500 mg. of nicotinic acid per day during the period of acute stress and for two or three days afterward. Such doses will not result in any wastage of vitamins by excessive urinary secretion if they are given to patients with illness or injuries comparable to those of the patients studied. After this early period, the doses might well be reduced to 200 mg. ascorbic acid, 10 mg. of thiamin, 10 mg. of riboflavin, and 75 mg. of nicotinic acid until convalescence is well-established. This

study has not been carried into later convalescence so no estimate of the needs at that time can be given.

SUMMARY

1. Six patients with severe acute surgical conditions have been studied with respect to the plasma level of ascorbic acid and the excretion of ascorbic acid, thiamin, riboflavin, and nicotinic acid.

2. Abnormally small amounts of one or more of these substances have been found in many specimens from all cases during the period of the acute illness.

3. This study gives some further support to the idea that large doses of ascorbic acid, thiamin, riboflavin, and nicotinic acid may serve a useful purpose in the care of acutely ill people.

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# THE TREATMENT OF ACUTE RENAL FAILURE BY PERITONEAL IRRIGATION*

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CERTAIN TYPES of acute renal failure need not be fatal if the period necessary for repair can be provided by utilizing an extrarenal pathway as a temporary substitute for the normal excretory function of the kidney. We have already published the experimental data[1] and one clinical experience[2] demonstrating the possibilities of continuous peritoneal irrigation for this purpose.

The peritoneal membrane has long been recognized to be an excellent dialyzing membrane, readily permeable to water and crystalloids.[3] Peritoneal irrigation makes use of this dialyzing capacity for the removal of diffusible substances from the plasma and ultimately from the extracellular fluid. Proper adjustment of the composition of the irrigating fluid prevents the depletion below normal concentration of the plasma of its normal constituents and thereby protects the chemical structure of the extracellular fluids.

We have referred elsewhere[1] to efforts by others† to utilize the peritoneum. In an experimental study in dogs[1] it was found that adequately conducted peritoneal irrigation would provide 40–75 per cent of normal kidney function in terms of urea clearance, correct acidosis, and prevent death from uremia following bilateral nephrectomy. In the present report our clinical experience with this method will be discussed.

## METHOD

*The irrigation fluid* is modified Tyrode's solution containing the following amounts of anhydrous substances per liter: NaCl 8.0 grams, KCl 0.2 gram, $CaCl_2$ 0.1 gram, $MgCl_2$ 0.1 gram, $NaH_2PO_4$ 0.05 gram, $NaHCO_3$ 1.0 gram, and dextrose 1.5 grams. It is prepared in large volume as follows: Fifteen liters of freshly distilled sterile water are run into a sterile 20-liter pyrex carboy. With the exception of sodium bicarbonate all the salts and the glucose for 18 liters of irrigating fluid are dissolved in two liters of distilled

* Part of the work described in this paper was done under a contract, recommended by the Committee on Medical Research between the Office of Scientific Research and Development and Harvard University.

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water and autoclaved. The $NaHCO_3$ for 18 liters is dissolved and autoclaved separately in a liter of distilled water. *It is important not to heat the bicarbonate solution with the other salts and glucose because of precipitation of calcium and magnesium salts and the production from glucose of toxic substances (probably aldehydes), which may be fatal.* Sterile solutions in small volume of the sodium salt of heparin (0.25–0.50 mg. per liter), of penicillin (2,500–5,000 units per liter) and of sulfadiazine (60–120 mg. per liter) together with the solutions of the salts and glucose are added to the water in the carboy at room temperature. Heparin is used to prevent the formation of fibrin and intestinal adhesions. Penicillin is used for prophylaxis against infection. Sodium sulfadiazine should not be added if renal sensitivity to sulfonamides is present or suspected.

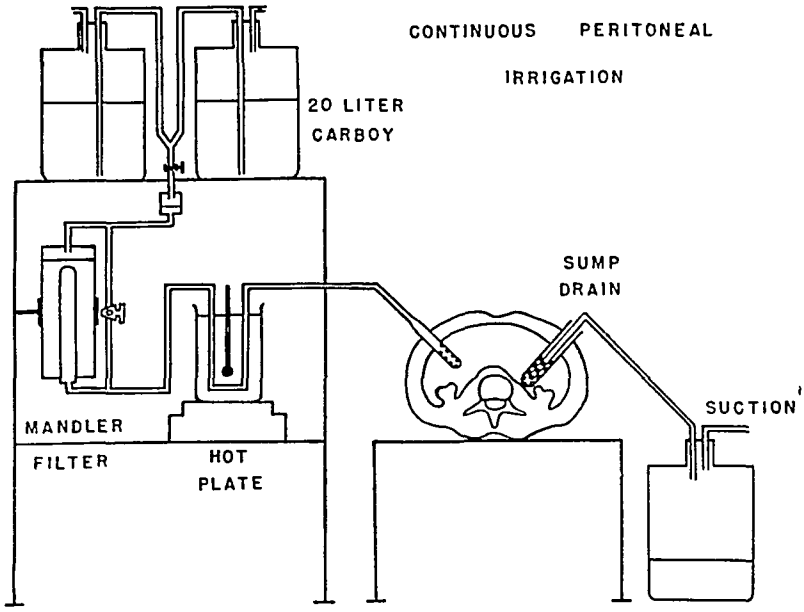



FIG. 1.—Diagrammatic representation of the circuit for continuous peritoneal irrigation.

Occasional modifications in the composition of the fluid were made, as indicated in the case reports. Further changes may be indicated as more experience is acquired. Since edema of the peritoneal membrane does not occur in consequence of irrigation, protein is not used as a rule. When protein seems indicated (as in Case 4), gelatin is used, since the large amount of protein required makes the use of human albumin impracticable, though probably preferable. If gelatin solution, which is acid in reaction, is used it should be brought to pH 7.5 with concentrated NaOH.

The fluid flows by gravity from two elevated carboys through siphon tubes, joined by a Y-tube, through a drip-bulb, then either directly or preferably through a Mandler (Berkefeld) filter to a glass U-tube in a water bath (40°C.–45°C.) and thence to the peritoneal inlet-tube (Fig. 1). The filter candle is eight inches long and one inch in diameter and permits a flow

of 40–60 cc./min. of a protein-free solution when the carboys are elevated two to three feet above the bed, as indicated in the photograph (Fig. 2). The inlet tube is a rubber catheter or a perforated small stainless steel tube. The outlet tube used in earlier cases was a whistle-tip catheter or a large-bore mushroom-tip catheter connected to a receiving carboy on the floor. The outlet tube proved unsatisfactory because of frequent plugging. Accordingly, in later cases a stainless steel sump-drain (Figs. 1 and 3), which is similar to the metal-perforated suction tube commonly available in operating rooms, was used as an outflow tube attached to a constant suction line. This has

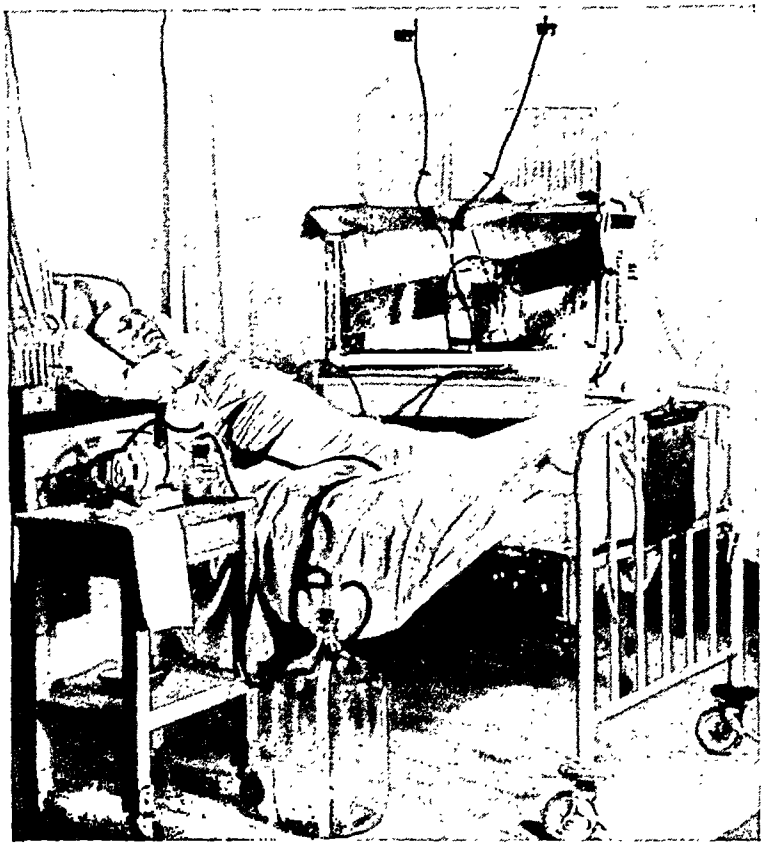


FIG. 2.—Photograph of apparatus for peritoneal irrigation.

proved entirely satisfactory and remains patent indefinitely. The inflow and the outflow tubes are inserted under local anesthesia into the peritoneal cavity, through small incisions, one in each flank. The sump-drain is directed into the cul-de-sac.

*Collateral therapy,* referred to in the case reports, is necessary for maintaining nutrition and water-soluble vitamin balance, correcting anemia, acidosis, hypoproteinemia and for the treatment of associated disease.

## CASE REPORTS

CASE 1.—B.I.H. No. 82847: I. E., female, age 49, was transferred to us from another hospital because of uremia caused by ureteral obstruction due to recurrent carcinoma of the cervix. She had entered the other hospital complaining of headache, anorexia, nausea, vomiting, and weight loss. Examination at that time showed her to be alert and coöperative. She was afebrile. She had purpuric spots on the arms

FIG. 3-A

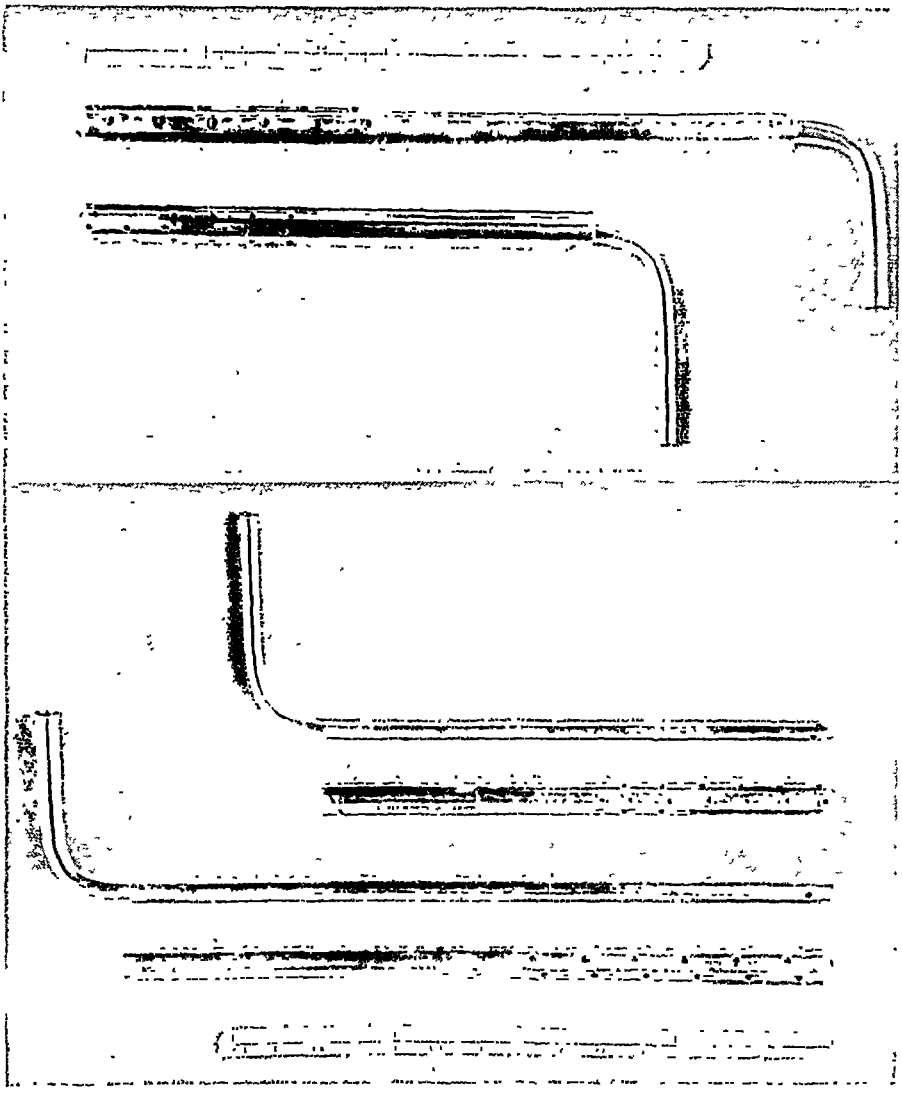


FIG. 3-B

FIG. 3-A and FIG. 3-B.—Sump-drain.

and legs and multiple fresh hemorrhages in the optic fundi. The blood pressure was 230/120. The apex of the vagina was fixed in a hard irregular tumor mass which extended laterally to fill the pelvis. The urine contained 2+ albumin and occasional white and red cells. *The hemoglobin was 100 per cent. The blood N.P.N. was 105* mg. per cent, the blood urea N 83 mg. per cent. At cystoscopy, no excretion of phenolsulfonphthalein was observed from the left ureter and only 2 per cent from the right ureter in ten minutes. Catheters reached the kidneys through tortuous ureters. Retrograde pyelograms showed dilatation of both renal pelves.

Nausea and vomiting necessitated parenteral alimentation. In spite of an adequate fluid intake, the total urine output was 10 to 40 cc. per 24 hours in each of the last four days prior to transfer to this hospital. Headache increased and mental alertness diminished. A pericardial friction rub appeared. She showed generalized edema. The patient's condition and prognosis were too poor to warrant nephrostomy or ureterostomy.

Upon transfer to this hospital two mushroom catheters were placed in the peri-

TABLE I

CASE 1. BLOOD UREA CLEARANCE* BY PERITONEAL IRRIGATION TESTED FOR SHORT PERIODS AT VARYING RATES OF FLOW

| Flow Rate Cc./Min. | Peritoneal Fluid Urea N Conc. Mg. % | Blood Urea Clearance Cc./Min. |
|---|---|---|
| 19 | 50.4 | 11.2 |
| 47 | 32.1 | 14.5 |
| 58 | 23.9 | 15.6 |
| 66 | 13.8 | 9.7 |
| 83 | 13.0 | 11.7 |
| 127 | 11.1 | 14.3 |

* Blood urea clearance by peritoneal route was calculated in the same way as urinary urea clearance using peritoneal fluid rate of flow and urea concentration in place of urinary values.

toneal cavity, which contained a large volume of free fluid (0 day, Fig. 4). The following day, when the blood N.P.N. was 195 mg. per cent, irrigation was started. Test periods of irrigation, with one-half hour intervals in between, at rates of flow varying from 19 cc./min. to 127 cc./min. indicated a maximum clearance of blood urea when the flow rate varied 40–60 cc./min. (Table I).

The next day continuous irrigation was carried out at a rate of 45 cc./min. for 24 hours. In this period 23 grams of urea were removed and an average blood urea clearance value of 16 cc./min. was attained. After an interval of four hours irrigation was resumed for another 24 hours, this time at an average rate of 60 cc./min. In this period 24 grams of urea were removed and the blood urea clearance value was 23

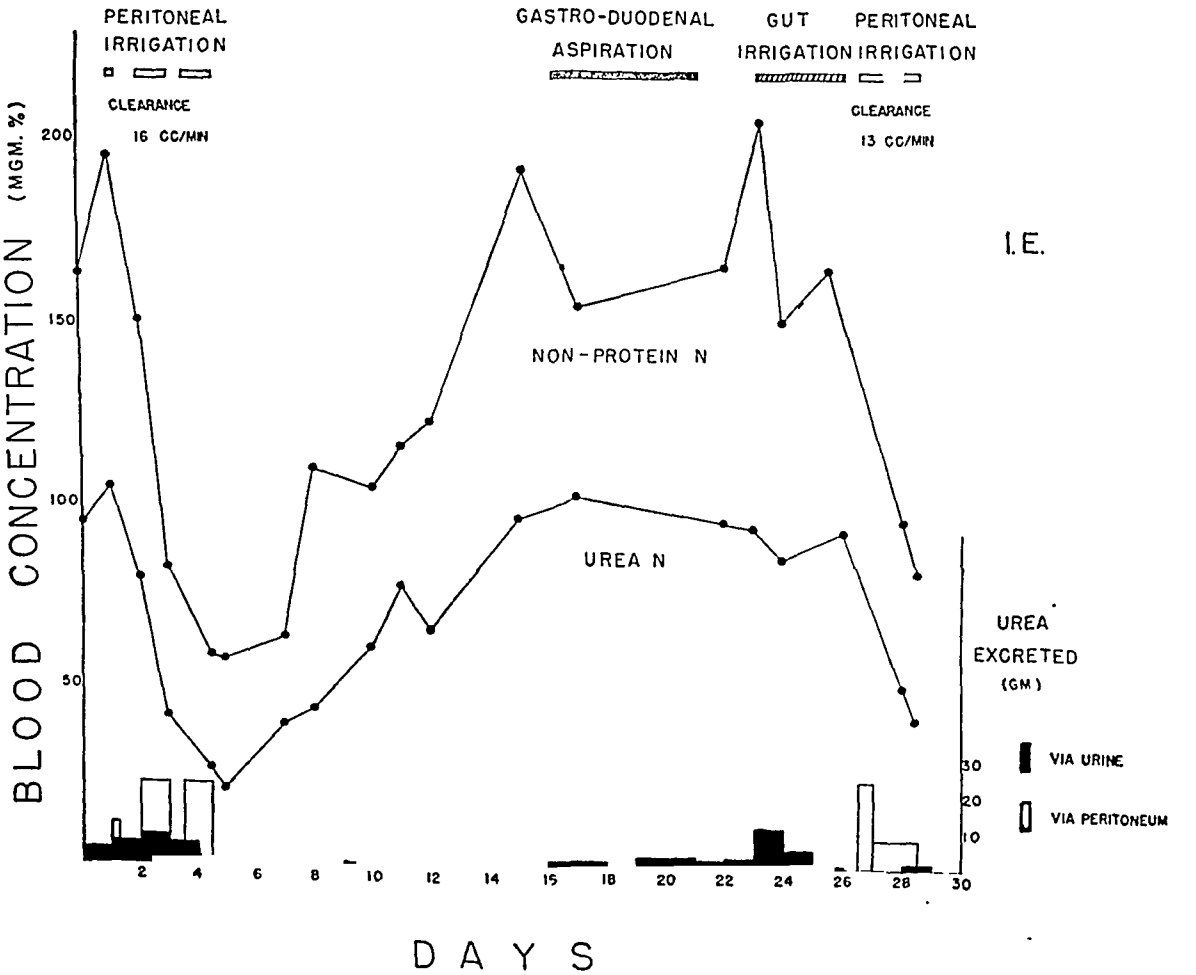



FIG. 4.—Case 1: Course of azotemia and daily urea elimination by the kidneys and by the peritoneum.

cc./min. After these two and one-half days of intermittent peritoneal irrigation, the blood N.P.N. concentration was 57 mg. per cent and the blood urea N was 21 mg. per cent. The patient was relieved entirely of headache, anorexia, nausea, and vomiting, and was alert. The blood pressure remained unchanged Transfusions were given to correct anemia. The irrigation produced no discomfort and the tubes required only occasional attention when the outflow catheter blocked.

During the period of peritoneal irrigation the volume of urine excreted increased up to 1,400 cc. per day. However the urea N content of the urine did not exceed 400 mg. per cent and total daily urinary urea excretion did not exceed ten grams. In view of the correction of the uremia and the apparent return of urine flow, peritoneal irrigation was discontinued.

Urinary output fell again and the clinical and chemical evidence of uremia gradually returned. Both peritoneal catheters were blocked. Nausea and vomiting recurred. A Miller-Abbott tube was passed and gastroduodenal suction instituted. The fluid removed was replaced by physiologic saline given intravenously. When the volume of aspirated fluid was less than 500 cc. per day its urea N content reached 64 mg. per cent, but when over 3,000 cc. per day was aspirated its urea N content was only 15 mg. per cent. Not more than one gram of urea per 24 hours was obtained by gastroduodenal aspiration. The uremic state was not improved.

Under spinal anesthesia an isolated 12-inch loop of ileum, with both ends exteriorized, was constructed in order to determine whether irrigation of the intestine in man would function adequately when peritoneal irrigation was impossible for one reason or another. Scattered omental and peritoneal metastases were found and histologic examination of one nodule disclosed undifferentiated carcinoma. No evidence of peritoneal inflammation from the preceding irrigation was found. The ends of the peritoneal catheters were firmly encased in omentum. Irrigation through the loop of

TABLE II

CASE 1: BLOOD UREA CLEARANCE BY IRRIGATION OF ILEAL LOOP TESTED FOR SHORT PERIODS AT VARYING RATES OF FLOW

| Flow Rate Cc./Min. | Irrigation Fluid Urea N Conc. Mg. % | Urea Clearance Via Intestine Cc./Min. | Urea Clearance Via Intestine Cc./Min./In. Intestine Length |
|---|---|---|---|
| 7.8 | 7.0 | 0.6 | 0.5 |
| 14.6 | 3.3 | 0.54 | |
| 15.5 | 2.9 | 0.48 | .04 |
| 15.8 | 3.0 | 0.52 | |
| 32.2 | 1.4 | 0.52 | |
| 46.0 | 0.7 | 0.36 | .03 |
| 63.0 | 0.5 | 0.34 | |
| 166.6 | 0.2 | 0.31 | |

ileum for short test periods at various rates showed so poor a clearance of blood urea (Table II) as to indicate that perfusion of a loop 200 inches long would be required to achieve a blood urea clearance of 10 cc. per minute, a rate which is approximately the minimum clearance necessary to avoid the development of uremia.[4] In the next three days, during which postoperative convalescence was entirely satisfactory, continuous irrigation through the loop at a rate of about 15 cc./min. was performed. The average urea clearance value per 24 hours was 0.56 cc./min. and the total amount of urea removed in the 24-hour period was only 0.1 Gm. (Fifty per cent magnesium sulfate irrigated through the loop was ineffective in increasing fluid and urea output and produced nausea and vomiting.) The blood urea N level was not improved and the patient's clinical condition became steadily worse. She lapsed into uremia and seemed moribund.

Two straight catheters were then introduced into the peritoneal cavity, under local anesthesia. They were passed with the aid of a stylet alongside the emerging

ends of the isolated loop of intestine. In the subsequent 24 hours, 38 liters of fluid were irrigated through the peritoneal cavity and 30 liters in the following 36 hours. An average blood urea clearance value of 13 cc./min. was attained and 35 Gm. of urea removed, with resulting satisfactory reduction in blood levels of N.P.N. and urea N. Clinical evidence of uremia disappeared. Irrigation was discontinued at this time.

Thereafter nothing was done to prevent the recurrence of uremia, steadily progressive anemia and malnutrition. The patient was kept comfortable by symptomatic therapy. She died a month and a half after irrigation therapy was ended. During this terminal period she excreted up to 1,000 cc. of urine daily and the progression of the uremic state was very slow.

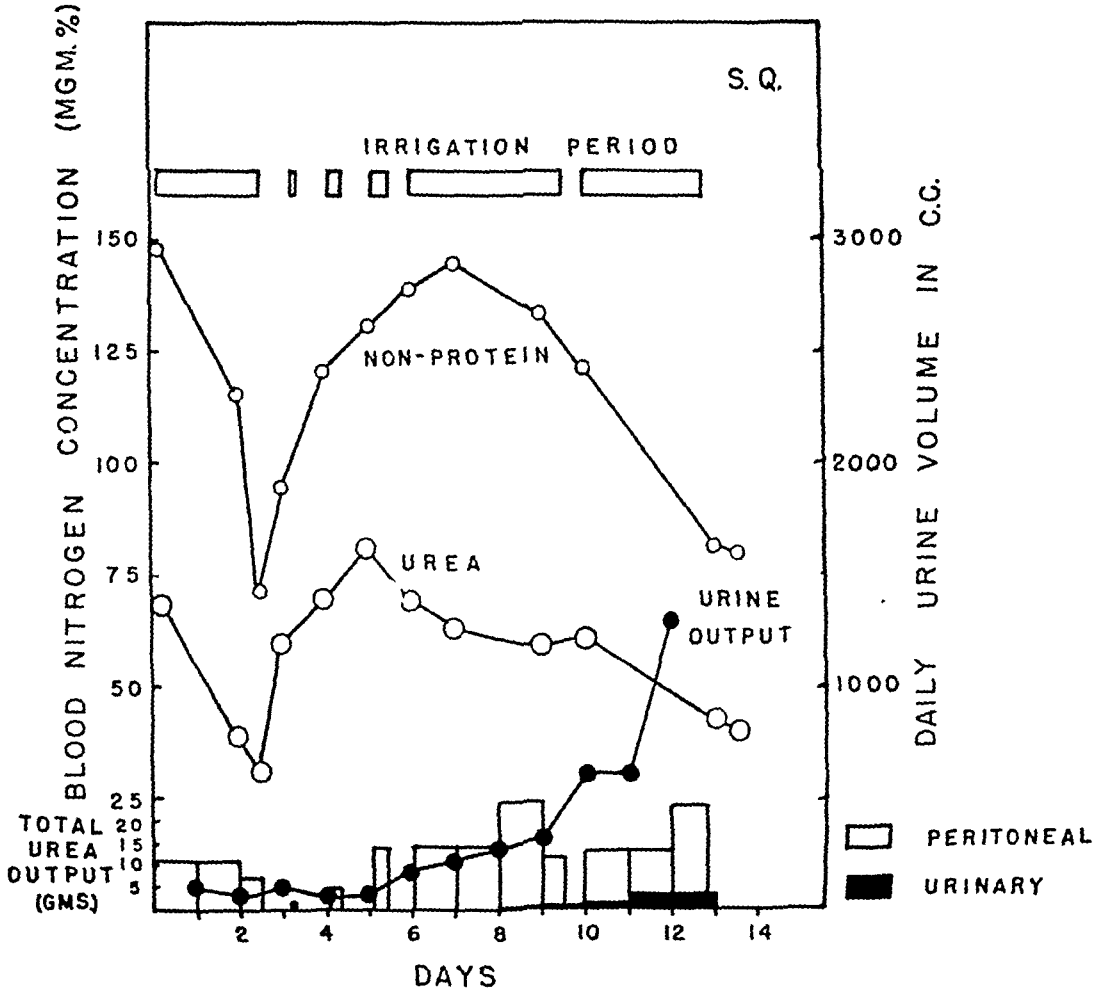



FIG. 5.—Case 2: Course of azotemia and daily urea elimination by the kidneys and by the peritoneum.

Autopsy showed the pelvis filled with carcinoma and scattered metastases in omentum and liver. The lower ureters were narrowed by tumor tissue so that there was considerable difficulty in forcing urine through them. The upper ureters were dilated. The kidneys were small and had dilated pelves and calices, surrounded by a narrowed rim of cortex. Microscopically they showed only edema and tubular degeneration. There was no evidence of peritonitis.

COMMENT: This case was our first clinical trial of continuous irrigation for uremia. It was learned that continuous peritoneal irrigation can be carried out without discomfort to the patient and without the production of peritonitis. An optimal rate of irrigation was determined and shown to be capable of rapidly reducing the blood levels of nitrogenous substances to normal with simultaneous correction of the uremic state.

It was learned further that irrigation of the intestine, which would have advantages over peritoneal irrigation if effective, is not a satisfactory substitute.

CASE 2.—B. I. H. No. 83789: S. Q., a 14-year-old girl, entered another hospital because of repeated nose bleeds of one month's duration. She was found to have a low grade fever, mycrocytic, hypochromic anemia, a loud systolic apical murmur, left axis deviation and an elevated sedimentation rate. The diagnosis of active rheumatic fever was made. She was given ferrous sulphate and 100 grains of aspirin daily. After five days of salicylate therapy, nausea, vomiting, marked hyperventilation and stupor were noted. The blood pH was 7.45 and $CO_2$ combining capacity was 20 volumes per cent. These findings were attributed to salicylate poisoning which is said to produce a primary respiratory alkalosis from central stimulation,[5] with a compensatory fall in alkali reserve. She was given 10 per cent $CO_2$ inhalations, morphine, 1.2 grams of ammonium chloride, 4,500 cc. of glucose in saline and 500 cc. of blood, later found to be incompatible. Seven hours after the transfusion she showed hemoglobinemia and hemo-

TABLE III

CASE 2: DAILY EXCRETION OF UREA BY PERITONEAL IRRIGATION AND BY THE KIDNEYS

| | Peritoneal Fluid | | | | Urine | | | | Blood | Blood Urea Clearance (Cc./Min.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Days* | Volume Cc. | Flow Rate Cc./Min. | Urea N Mg. % | Total Urea Gm. | Volume Cc. | Flow Rate Cc./Min. | Urea N Mg. % | Total Urea Gm. | Urea N Mg. % | Peritoneal | Renal |
| 0 | 9250 | 6.0 | 61 | 11.3 | 0 | — | — | — | 68 | 5.4 | |
| 1 | 9250 | 6.0 | 61 | 11.3 | 108 | .08 | 20 | .04 | 55 | 6.7 | |
| 2 | 9000 | 12.5 | 38 | 6.8 | 64 | .05 | 15 | .02 | 35 | 13.5 | |
| 3 | 2000 | 11.0 | 56 | 2.2 | 109 | .08 | 60 | .13 | 60 | 10.3 | |
| 4 | 3000 | 8.0 | 76 | 4.6 | 60 | .04 | 40 | .05 | 70 | 8.7 | |
| 5 | 9000 | 16.6 | 77 | 13.9 | 74 | .05 | 74 | .11 | 82 | 15.6 | |
| 6 | 18000 | 12.5 | 39 | 14.0 | 184 | .13 | 40 | .15 | 68 | 7.2 | |
| 7 | 18000 | 12.5 | 39 | 14.0 | 210 | .15 | 109 | .46 | 63 | 7.7 | 0.25 |
| 8 | 24000 | 16.6 | 50 | 24.0 | 260 | .18 | 89 | .46 | 60 | 13.8 | 0.27 |
| 9 | 12000 | 16.6 | 50 | 12.0 | 305 | .21 | 122 | .75 | 60 | 13.8 | 0.43 |
| 10 | 18000 | 12.5 | 37 | 13.3 | 610 | .43 | 78 | .95 | 62 | 7.5 | 0.54 |
| 11 | 18000 | 12.5 | 37 | 13.3 | 610 | .43 | 260 | 3.00 | 55 | 8.4 | 2.01 |
| 12 | 36000 | 40.0 | 32 | 23.0 | 1300 | .88 | 118 | 3.10 | 45 | 28.5 | 2.40 |

* From the start of irrigation; numbers correspond with days indicated in Fig. 5.

globinuria. The pH of the urine was 4.5. She was given sodium bicarbonate and sodium lactate. The temperature rose to 103° F. In the subsequent two days she voided no more than 30 cc. of urine per day. She remained hyperpneic and stuporous, with a blood $CO_2$ combining capacity at or below 30 volumes per cent. Diathermy to the kidney areas failed to increase urine output.

The patient was transferred to us 48 hours after the hemolytic reaction was recognized. On admission, she was pale, edematous and stuporous. She coughed frequently. There were diminished breath sounds and râles at both lung bases. The heart was enlarged, with a loud apical systolic murmur and thrill. Pulse rate was 110. The rectal temperature was 100.6° F., and the respiratory rate 30 per minute. The urine was clear and straw-colored, alkaline, sp. gr. 1.010, albumin 4+, 15–20 W.B.C. and R.B.C. The red cell count was 2.45 millions and the Hb 36 per cent. The blood N.P.N. was 78 mg. per cent. Chest roentgenograms showed mitral valvular disease, consolidation of both lower lobes, and questionable left pleural effusion.

In view of the brief duration of the anuria and the complicating illnesses, uremia was not considered the immediate primary problem. Accordingly, peritoneal irrigation was deferred for 36 hours. During this time she was given 1,000 cc. of blood in two transfusions, glucose in distilled water in small volume, parenteral penicillin (100,000

units per 24 hours) and sodium sulfadiazine (2.5 Gm. per 24 hours). Mental clarity improved and temperature and pulse returned to normal. The total urine output in this period was less than 30 cc.

Without removing the patient from bed, two whistle-tip rubber catheters were introduced, under local anesthesia, into the peritoneal cavity and irrigation was begun. Figure 5 and Table III indicate the effect of the irrigation in terms of total urea removed, changes in blood level of nonprotein and urea nitrogen and calculated urea clearance. In the early period flow rates considerably slower than optimal were used because recurring difficulty with the outflow tube led to recurring distention of the peritoneal cavity with fluid. Repeated adjustments of the outlet tube were necessary. In spite of this, significant blood urea clearance was achieved, blood nitrogen levels were markedly improved, the blood $CO_2$ combining capacity rose to 48 volumes per cent, and alertness returned. Nevertheless, she remained sick, exhibiting a low-grade swinging fever, evidence of congestive heart failure, pneumonia, and episodes of paroxysmal dyspnea, cyanosis and tachycardia. Gastric distention required suction drainage. The hemoglobin level was restored to 80 per cent by transfusion. She was fully digitalized and penicillin and sulfadiazine therapy were continued. Since she was no longer uremic and since the avoidance of abdominal distention was desired, peritoneal irrigation was almost completely discontinued for two days, during which the clinical and chemical evidence of uremia recurred. The $CO_2$ combining capacity dropped to 24 volumes per cent.

Accordingly, two large-bore mushroom-tip rubber catheters, instead of whistle-tip catheters previously used, were implanted in the peritoneal cavity through small lateral abdominal incisions made, under local anesthesia. No evidence of peritonitis was seen. Irrigation through these tubes proceeded satisfactorily although blockage of outflow did recur from time to time. The uremic state was corrected. During this period, ileus required almost continuous Miller-Abbott tube therapy. The peritoneal outflow fluid in the subsequent week remained sterile. On the last day of irrigation the colon bacillus was found in the outflow fluid. In spite of a complexity of confusing symptomatology chiefly referrable to the cardiorespiratory system, the general trend of the clinical condition was one of gradual improvement and all evidence of uremia eventually disappeared.

Meanwhile, there was evidence of recovery of renal function. On the second day of irrigation, 5.5 days after the transfusion reaction, 108 cc. of urine were excreted. On each of the subsequent four days from 60 to 110 cc. of urine were excreted. The urea content of this urine was less than 75 mg. per cent, so that the total urinary excretion of nitrogen was negligible and uremia recurred when peritoneal irrigation was interrupted. On the sixth day of irrigation the urine volume increased to 184 cc. and continued to increase thereafter until it reached 1,300 cc. on the 12th day of irrigation, or 15.5 days after renal shutdown. The urinary urea excretion, however, did not keep pace with the recovery of volume output and was still insufficient to prevent recurrence of uremia. Since improvement in kidney function seemed to be progressive, irrigation was temporarily discontinued. On the next day (16th day) when she seemed very much better and indeed apparently convalescing, she suddenly died, following a severe paroxysm of dyspnea. Postmortem examination disclosed multiple small pulmonary emboli, the sources of which were mural thrombi in the right ventricle and auricle. There was a minimal amount of rhemuatic heart disease and vegetative endocarditis. There was no peritoneal reaction of consequence at the site of the catheters but 100 cc. of turbid fluid containing the colon bacillus was found in the pelvis, which also showed a low grade inflammation with delicate, fibrinous adhesions between loops of intestine. The kidneys were swollen and pale except for congested pyramids. Microscopically, they showed a few brown granular hemoglobin casts in the tubules. Most of the tubules were dilated and lined with flattened regenerated epithelium.

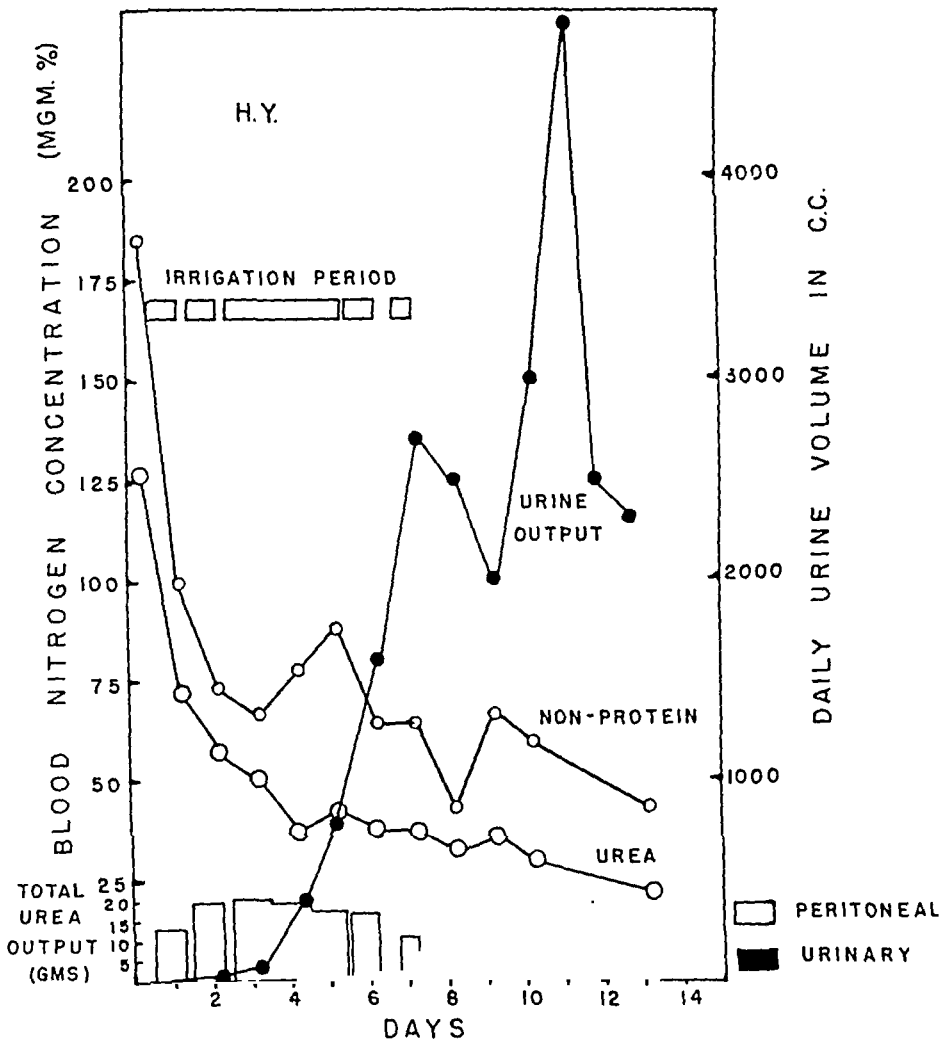



FIG. 6.—Case 3: Course of azotemia and daily urea elimination by the kidneys and by the peritoneum.

COMMENT: The immediate cause of death was multiple pulmonary emboli. In spite of the multiplicity of grave disorders complicating the acute renal shutdown, peritoneal irrigation achieved the purpose of eliminating the uremic state except during the period when the first set of catheters stopped working well. Renal shutdown was virtually complete for 13 days after the incompatible transfusion, at which time significant diuresis began (over 500 cc. per day) and the urinary urea output was increasing so that recovery sufficient to maintain electrolyte equilibrium might have been expected shortly. Although the recovery of function after renal shutdown from an incompatible transfusion begins, as a rule, at about this time, it is possible that elimination of the uremic state relieves the kidney, as it presumably must all other tissues, of an added burden which itself may prolong the recovery period. Peritoneal irrigation, therefore, may serve not only to delay death until renal recovery takes place but may also shorten the period necessary for recovery.

The colon bacillus infection of the peritoneum appeared on the 12th day of irrigation. Its extent and severity did not seem to contribute significantly to the lethal outcome.

It was clear from this experience that a catheter would not do as an outflow tube — so that in the next patient a stainless steel sump-drain was used instead. This functioned with complete satisfaction.

CASE 3.—B. I. H. No. 85197: H. Y. This case has been reported fully elsewhere.[3] A summary of the pertinent data follows: A man, age 51, developed anuria five days before admission to the hospital after 14 days of sulfathiazole therapy for an acute infection. After admission to the hospital, excessive parenteral fluids produced generalized edema and uremic intoxication became extreme. A study of the urinary tract disclosed parenchymatous renal damage. After five more days of anuria, at a time when the patient seemed moribund, peritoneal irrigation was started (0 day, Fig. 6 and Table IV). In spite of severe ileus, pulmonary edema and acidosis, the azotemia was reduced to near normal values within 48 to 72 hours. On the fourth day of irrigation, after 14 days of virtually complete anuria, urine output began and increased steadily thereafter. The urinary urea excretion reached a level capable of

TABLE IV

CASE 3: DAILY EXCRETION OF UREA BY PERITONEAL IRRIGATION AND BY THE KIDNEYS

| | Peritoneal Fluid | | | Urine | | | Blood |
|---|---|---|---|---|---|---|---|
| Days* | Flow Rate Cc./Min. | Urea N Conc. Mg. % | Blood Urea Clearance Cc./Min. | Flow Rate Cc./Min. | Urea N Conc. Mg. % | Blood Urea Clearance Cc./Min. | Urea N Conc. Mg. % |
| 1 | 25 | 24.4 | 8.4 | — | — | — | 72.7 |
| 2 | 33 | 27.4 | 14.5 | 0.02 | 85.0 | 0.03 | 62.2 |
| 3 | 25 | 28.1 | 13.8 | 0.04 | 66.0 | 0.05 | 50.6 |
| 4 | 25 | 26.0 | 17.2 | 0.28 | 75.0 | 0.55 | 37.8 |
| 5 | 13 | 31.2 | 9.5 | 0.55 | 50.0 | 0.65 | 42.8 |
| 6 | 35 | 21.0 | 19.4 | 1.10 | 62.5 | 1.82 | 37.8 |
| 7 | 29 | 26.5 | 21.0 | 1.87 | 32.5 | 1.65 | 36.7 |
| 8 | | | | 1.74 | 145.0 | 7.60 | 33.3 |
| 9 | | | | 1.40 | 255.0 | 9.70 | 36.8 |
| 10 | | | | 2.30 | 193.0 | 14.80 | 30.0 |
| 11 | | | | 3.30 | 225.0 | 24.70 | |
| 12 | | | | 1.74 | 370.0 | 26.00 | |
| 13 | | | | 1.60 | 392.0 | 28.50 | 22.0 |

* From the start of peritoneal irrigation; numbers correspond with days indicated in Figure 6.

preventing uremia on the seventh day of irrigation. At this time the irrigation was stopped. Progressive improvement in renal function continued thereafter and the patient left the hospital quite fit one week later, at which time renal function, in terms of urea clearance, was 33 per cent of normal. One month later renal function, in terms of urea clearance, was 50 per cent of normal and the P.S.P. test was normal. A year later kidney function was no better.

Pulmonary edema was considerable and distressing on the third day of irrigation. All parenteral fluids were omitted from then on. Glucose was added to the peritoneal fluid to correct starvation acidosis. At the same time troublesome ileus required tube suction, which yielded 6,000 cc. of fluid on the third and fourth days. The edema rapidly cleared thereafter. On the third day of irrigation, *E. coli* appeared in the outflow liquid, but there was no other clinical evidence of peritonitis even though this organism and leukocytes persisted until irrigation was stopped. On the first and second days after irrigation was discontinued, one million units of streptomycin in a liter of saline was injected intraperitoneally even though the patient seemed not to require chemotherapy.

COMMENT: Parenchymatous damage to the kidney from sulfathiazole is usually fatal. This patient was almost moribund when peritoneal irrigation was started. A cure seems to have been achieved in this patient by this method.

CASE 4.—C. W., a 19-year-old girl, entered another hospital for the surgical correction of cardiospasm. An esophagoplasty was done through the left chest. During the operation she received 500 cc. of Type-A blood (Rh positive). The patient's blood group was thought to have been Type A but later investigation demonstrated her to be Type-O (Rh positive). The patient's preoperative blood pressure was 100/70 mm.Hg. There was no shock during the operation. However, in the immediate postoperative period there was an abrupt drop in blood pressure to 70/40 mm.Hg. accompanied by respiratory difficulty and marked shift of the mediastinum to the right. The respiratory distress and mediastinal shift were corrected by the aspiration of bloody fluid and air from the left chest, after which the blood pressure recovered to a level of 85/55 mm.Hg. and reached normal two days later. Fifteen hundred cubic centimeters of 5 per cent glucose in water plus sodium sulfadiazine were given the afternoon of the day of operation. Mental dulness bordering upon stupor was present through the afternoon and night. The next morning the patient was found to be anuric. Spectrophotometric examination of the blood plasma disclosed the presence of a severe hemolytic transfusion reaction. A roentgenogram disclosed left pleural effusion and atelectasis. The blood N.P.N. was 70 mg. per cent, the serum chlorides 86 mEq./L and the serum $CO_2$ 27.8 mEq./L. She was given 80 cc. of molar sodium lactate in 2,000 cc. of 5 per cent dextrose in water intravenously and 500 cc. of Type-O blood. In the 24 hours of the first postoperative day, 80 cc. of black urine were obtained from an inlying catheter. Tables V, VI, VII and VIII list the pertinent chemical findings and fluid balance data from this day onward. The fluid taken by mouth throughout the postoperative period was negligible in amount.

On the second postoperative day the patient was alert and comfortable. Laboratory data showed: blood N.P.N. 86 mg. per cent, B.U.N. 81 mg. per cent, serum chlorides 92 mEq./L, serum $CO_2$ 29.2 mEq./L, serum sodium 133 mEq./L, serum potassium 5.2 mEq./L, and plasma protein 5.1 Gm. per cent. In the 24 hours of the second postoperative day she was given 2,000 cc. of 10 per cent glucose in water and 1,000 cc. of whole blood. Her urine output in this period was 50 cc.

On the afternoon of the second postoperative day peritoneal irrigation was instituted. An inflow tube and a sump-drain were introduced into the lateral aspects of the peritoneal cavity under local anesthesia and peritoneal irrigation at a rate of 40 cc./min. was started. The inflow fluid was passed through a Mandler (Berkefeld) filter. Penicillin and Vitamins B, C, and K were given parenterally each day. Irrigation proceeded smoothly, produced no discomfort and required no adjustment to maintain outflow. Because of recurring respiratory difficulty the patient remained in a high sitting position, which is not optimal for peritoneal irrigation.

On the third postoperative day the patient seemed well except that respiratory distress required two taps of the left chest which yielded about 2,000 cc. of bloody fluid. The blood N.P.N. was 70 mg. per cent and serum $CO_2$ 23.3 mEq./L. She was given 2,600 cc. of 5 per cent glucose in water and 500 cc. of blood. The urine output was 30 cc. A menstrual period began. In view of the uterine bleeding and the reaccumulation of bloody fluid in the left chest, the danger from heparin in the irrigating fluid was considered but since the blood clotting time and prothrombin time were found to be normal repeatedly, heparin in the irrigating fluid was continued. The outflow fluid had a slightly uriniferous color and odor. The blood pressure had risen to 180/90. The extracellular fluid space, as measured by radioactive sodium, was found that evening to be 15,000 cc. or 29.5 per cent of the body weight (50.9 Kg.), a considerable increase over the normal extracellular space, which is 18–22 per cent of

body weight. This suggested the development of edema, which was not yet obvious clinically. It is possible that the chest fluid and the intraperitoneal fluid may have accounted in part for the increased extracellular fluid space.

The presence of edema was evident the next (fourth) day. Another chest tap was required and removed a liter of brown fluid. A transfusion of 500 cc. of blood and 2,000 cc. of 15 per cent glucose in water were given intravenously. The urine output for the day was 60 cc. The plasma sulfadiazine level was 4.9 mg. per cent, derived entirely from the irrigation fluid. Thereafter it was omitted from the irrigation fluid because of the remote possibility that it might retard renal recovery. Chest signs indicative of slight pulmonary edema were found. Digitalization was begun.

On the fifth postoperative day the patient's respirations were rapid, deep and labored. There was no evidence of recurrence of pleural effusion and the respiratory changes were attributed to a combination of pulmonary edema and acidosis. The serum $CO_2$ was 16.9 mEq./L, serum chlorides 110 mEq./L, blood N.P.N. 70 mg. per cent, B.U.N. 45 mg. per cent, plasma protein 5.0 Gm. per cent and the venous blood pH 7.38. By the dye and hematocrit methods the blood volume was found to be 3,500 cc. (7.1 per cent of body weight) and the plasma volume 1,950 cc. (4.0 per cent of body weight) — both values being somewhat lower than normal. Generalized edema was marked. The extracellular "thiocyanate space" was 29,400 cc., or 58 per cent of body weight. Part of this increase may have been due to an intracellular shift of normally extracellular ions as indicated by the somewhat reduced serum sodium (131.0 mEq./L.) and elevated serum potassium (6.2 mEq./L.). Fifteen hundred cubic centimeters of 10 per cent glucose in water and 600 cc. of plasma were given through the day.

By midnight the dyspnea was very marked and was not relieved by the aspiration from the left chest of 300 cc. of fluid. To reduce pulmonary edema 800 cc. of a solution containing 30 per cent glucose and 25 per cent human albumin was administered intravenously in a period of 5.5 hours. At the end of this time severe pulmonary edema with extreme dyspnea, frothy sputum, cyanosis, and loss of consciousness was manifest. Treatment included morphine (8 mg.), atropine (0.65 mg.), continuous oxygen inhalation at a positive pressure of 1 cm. of water, phlebotomy of 300 cc. and the application of venous tourniquets to the extremities. Gradual improvement occurred over a period of three hours, leaving the patient conscious but dyspneic, with poor color and with râles throughout both lungs. In the hope of removing the excess water from the patient's body by way of the peritoneal membrane, almost all sodium (as well as all other electrolytes) were eliminated from the irrigation fluid, which was made hypertonic by a combination of 5 percent gelatin and 2.5 per cent glucose. The Mandler filter was removed from the inflow circuit to allow the free passage of the gelatin. Irrigation with this solution was begun at noon of this day. By early evening the pulmonary edema seemed considerably diminished. At 10:30 P.M. the patient was found to be in extreme shock, unconsciousness, with cold, pale skin and a thin weak pulse. The systolic blood pressure which had been at a level of 150 mm.Hg. all through the day up to 6:00 P.M. was now unobtainable. The irrigation was stopped and 100 cc. of 50 per cent glucose plus 500 cc. of blood were given intravenously. The systolic blood pressure was restored to 110 mm.Hg. by midnight and it remained at that level. A slow intravenous drip of 30 per cent glucose in water was continued. Respirations remained labored and the patient remained unconscious.

The next morning the patient was still unconscious. The coma was attributed to cerebral edema. The generalized and pulmonary edema seemed definitely diminished. The blood N.P.N. was 42 mg. per cent, the B.U.N. 40 mg. per cent and the serum $CO_2$ 20.4 mEq./L. To further reduce the edema, particularly the cerebral edema, peritoneal irrigation with 5 per cent gelatin, and 2.5 per cent glucose was resumed at noon. Within 30 minutes the blood pressure dropped to 80/50 mm.Hg. and in the subsequent 2.5 hours to 60/40, after which the irrigation was stopped and the systolic pressure

slowly returned to 100 mm.Hg. A generalized tonic and clonic convulsion, accompanied by apnea, lasting one minute, occurred. There was a marked rise in hemoglobin concentration and hematocrit from the previous day's levels of 11.6 Gm. per cent and 42 per cent, respectively, to 15.8 Gm. per cent and 57 per cent, respectively, and a concomitant fall in serum sodium and chloride from 131 and 106 mEq./L., respectively, to 114 and 88 mEq./L., respectively. Eighty cubic centimeters of molar sodium lactate was given intravenously because of the low serum sodium. The peritoneal irrigating fluid was changed to a simple solution of 5 per cent glucose in water which was brought to the physiologic concentration of sodium and chloride by the addition of sodium lactate and sodium chloride.

At 2:30 A.M. of the eighth postoperative day, the seventh day of peritoneal irrigation, convulsions recurred, the blood pressure dropped and in spite of treatment in the next four hours with sodium phenobarbital, sodium lactate and whole blood transfusion, the patient died. By the time of death the subcutaneous edema had disappeared.

The patient had never shown systemic or any local evidence of sepsis during her illness. The rectal temperature remained below 100° F. in the early postoperative days and she was completely afebrile in the two days before death. Histologic examination of the output fluid showed no leukocytes. On the last day of irrigation a very few colonies of bacteria were grown from the outflow fluid. These were identified as *Staph. albus, E. coli, Cl. welchii* and diplococci of the enterococcus type.

Postmortem examination showed typical transfusion reaction kidneys, but no other cause of death. There was no peritonitis, adhesions or evidence of tissue injury in the peritoneal cavity. Subcutaneous and cerebral edema were absent and pulmonary edema was minimal.

The report of the completed examination of the kidneys is not yet available.

COMMENT: This patient was given 500 cc. of incompatible blood while under general anesthesia and became almost completely anuric immediately thereafter. She excreted no more than 80 cc. of urine on any of the subsequent eight days of life. Peritoneal irrigation for approximately six of those days was successful in reducing the blood N.P.N. level to near normal limits. The irrigation proceeded with a minimum of adjustment, produced no discomfort, caused no intra-abdominal damage or infection, and did not interfere with the remainder of the care of the patient.

Death probably was due to incorrect management of the water balance problem. This may have been due in part to a division of responsibility in the management of this patient between ourselves and the resident staff at the hospital at which the patient was being treated. She received water in excess, as the fluid intake data demonstrated. At least partly because of this (there is also a possibility that water might be absorbed in excess of normal requirements from the irrigating fluid) she developed pulmonary and probably cerebral edema. The water was given as a vehicle for glucose to counteract starvation and acidosis, but the glucose could have been given in much higher concentration and smaller fluid volume. When the tissue edema was massive and pulmonary edema severe, hypertonic glucose was given, but concentrated albumin was also given and both were given too rapidly. Even though the plasma volume was a little less than normal, the addition of concentrated albumin proved to be unwise since the resulting rapidly induced hydremic plethora precipitated an even more severe pulmonary edema with

the disastrous results described. The treatment then needed to correct the situation resulted in a considerable depletion of an originally less than normal blood volume. The administration of oxygen at positive pressure in expiration as well as in inspiration may have further reduced cardiac output. The subsequent use of an hypertonic and salt poor irrigation fluid to reduce the edema may have reduced plasma volume more rapidly than it could be restored from interstitial fluid, so that while pulmonary edema diminished, extreme shock developed and was unrecognized for several hours, during which the patient was in a high sitting position with a very low blood pressure. Shock was subsequently corrected, but the period of poor blood flow may well have done damage which contributed to the fatal outcome. The patient never regained consciousness thereafter. A second period of peritoneal irrigation with hypertonic salt-poor fluid resulted in another drop in blood pressure.* A marked rise in hematocrit and hemoglobin concentration substantiated the impression that the plasma volume was being too rapidly reduced.

The terminal convulsions are not explained except on the basis of cerebral damage from the antecedent edema or shock or possibly because of reduced ionizable calcium, because calcium was omitted from the irrigating fluid in the last two days and the plasma calcium concentration did drop somewhat below normal.

There is no way of knowing if or when recovery of kidney function might have occurred. The dose of incompatible blood was large, but there is no reason to believe that renal healing might not have taken place if the patient could have been kept alive for the required time.

The electrolyte pattern of the plasma was kept near normal limits. Figure 7 is the diagram adapted from Gamble,[6] showing the electrolyte composition of the plasma of the patient on the sixth day of almost complete anuria (day 5, Table V) compared with that of normal plasma. On this day the patient's serum $CO_2$ concentration was the lowest recorded, but normal blood pH was maintained nevertheless.

The total disappearance of the edema before death was ample testimony to the efficacy of peritoneal irrigation with hypertonic solutions, for removing water from the body. In spite of the complex and disappointing developments peritoneal irrigation served its primary purpose. But it is at the same time evident that such a tool for the control of fluid and electrolyte balance cannot be successfully instituted without the exercise of extreme caution and without well considered judgment as to the kind of supplementary therapy needed for nutritional balance.

Discussion.—The foregoing experiences show emphatically that this method is still in the experimental stage. What is so far established is

* This happened so quickly that a toxic effect of the solution was suspected. To exclude the suspicion of toxic material in the irrigation solution, 300 cc. of the solution was given intravenously during 2–3 hours to an 8-Kg. dog without immediate or delayed harmful effect.

TABLE V

CASE 4: DAILY BLOOD ANALYSIS

| Day* | Blood N.P.N. Mg. % | Blood Urea N Mg. % | Serum $CO^2$ mEq./L. | Serum Chloride mEq./L. | Serum Sodium mEq./L. | Serum Potassium mEq./L. | Serum Calcium Mg. % | Serum Phosphorus Mg. % | Serum Protein Gm. % | Serum Magnesium mEq./L. | Venous Blood pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7) | | 27.8 | 86 | | | | | 5.1 | | |
| 2 | 86 | 81 | 29.2 | 92 | 133 | 5.7 | | | | | |
| 3 | 70 | 69 | 23.3 | 94 | | | | | 5.1 | | |
| 4 | 90 | 51 | 21.7 | 102 | 132 | 6 2 | | | 5.0 | | |
| 5 | 70 | 45 | 16.9 | 110 | | | 7.8 | 5.8 | 5.0 | | 7.38 |
| 6 | 60 | 42 | 22.2 | 106 | 131 | 5.5 | 7.8 | 6.8 | 5.7 | 2.4 | |
| 7 | 42 | 40 | 20.4 | 88 | 114 | 7.1 | 8.0 | 6.7 | | | |

* Days subsequent to transfusion reaction.

(1) that a properly performed peritoneal irrigation can eliminate all clinical and chemical evidence of the uremic state; (2) that significant improvement can be achieved within 36 to 48 hours; (3) that the total time required will vary with the duration and severity of the uremia, degree of saturation of the tissues with retained products, degree of dehydration or edema, the nutritional state, food intake, the rate of protein catabolism, the presence of associated disease and the rate of efficiency of peritoneal irrigation; (4) that irrigation will not injure the peritoneal structures; and (5) that the efficiency

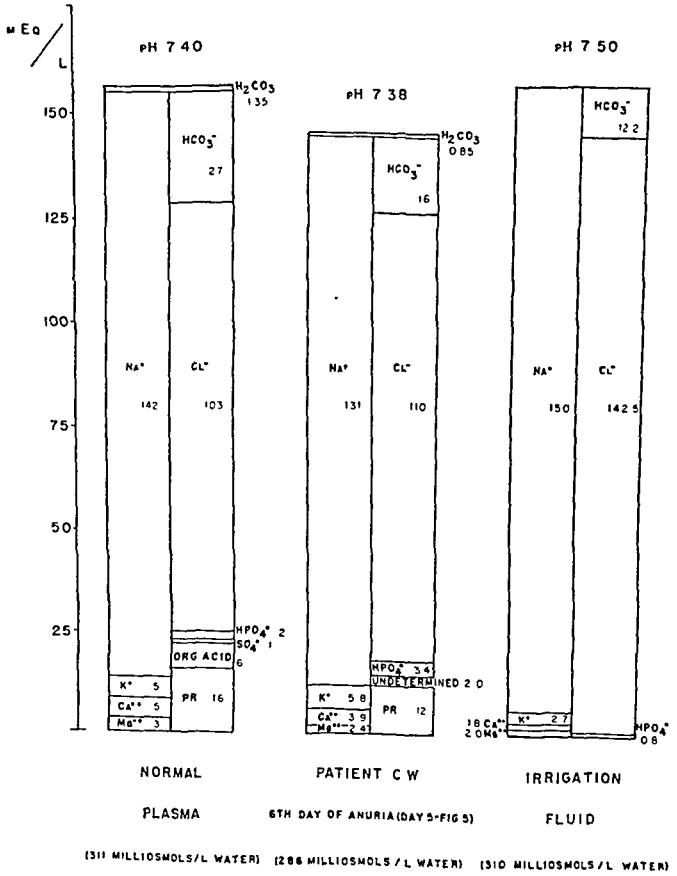



FIG. 7.—Gamble diagram[6] of the electrolyte composition of normal plasma, the plasma of Case 4, and of the peritoneal irrigation solution.

of irrigation so far as blood urea clearance is concerned does not diminish with time and exceeds the minimal degree (10 per cent–15 per cent) of renal excretory function necessary to avoid reaccumulation of nonprotein nitrogen or urea.

It is possible that the uremic state imposes a further burden on the damaged kidneys, as it does on all other tissues and that the repair of the renal injury is facilitated by the removal of the uremic state. The time necessary for repair of the renal injury and recovery of sufficient renal function can not be foretold. It will vary from one type of injury to another and from case to case with the same type of injury. Lesions capable of repair within a few weeks should be amenable to this therapy because it probably can be continued safely that long. To date the longest period we have carried the treatment is 12 days.

The danger of peritonitis has been the chief hazard. With the introduction of a bacterial filter on the inlet side of the irrigating system, with chemotherapy and with careful isolation of the abdominal wounds and tubes by proper dressings, this danger is minimized very substantially. The organisms isolated from the peritoneal drainage fluid were *E. coli* after 12 days in Case 2, *E. coli* after three days in Case 3, in which it produced no significant clinical effects, and *E. coli, Cl. welchii, Staph. albus* and enterococci in Case 4, in which at postmortem there was no evidence of peritonitis. Objection to sulfonamides on the ground of inflicting additional renal injury may be valid and may justify restricting chemotherapy to penicillin and streptomycin when available. The placing of the inflow and outflow tubes should be done with such care that the possibility of dislodgement and the need to replace them should be avoided. It is certain that a rubber catheter of whatever design as an outflow tube will not answer this need and should not be attempted. A sump-drain made of inert metal (stainless steel) is completely satisfactory and devoid of discomfort to the patient.

The most meticulous attention to fluid and electrolyte balance is continuously required. Neglect to do so, as Case 4 demonstrates, will vitiate the whole effort. In uremia "the defense of the chemical structure of the extracellular fluid is of much more importance from the point of view of survival than reduction of azotemia."[7]

Pulmonary edema was present in Cases 2, 3 and 4—in all instances because of the intravenous administration of fluid in excess of tissue requirements for fluid in the anuric state and because of acidosis. The fluid requirement during renal suppression consists only in water lost by vaporization, which is about a liter per day, *i.e.*, 0.5 cc./Kg./hr.,[6, 8] unless fever, vomiting, diarrhea or sweating are present. All these patients received water in excess of what they required; Cases 2 and 3 before irrigation was started, in what was an obviously futile effort to stimulate diuresis; Case 3 for the first two days after it was started, and Case 4 for five days after irrigation was started. Since food intake is likely to be either inadequate or *nil*, intravenous fluid is necessary purely as a vehicle for glucose (and possibly for

amino-acids if treatment is needed for many days) to counteract starvation acidosis and to spare protein breakdown, but the fluid must be given in as small a volume as possible. Four hundred grams of glucose in 1,200 cc. of water should substantially satisfy the caloric need and prevent acidosis. It should be given slowly to avoid hydremic plethora and rapid loss of glucose into the irrigating fluid.

TABLE VI

CASE 4: DAILY URINE OUTPUT AND INTRAVENOUS FLUID ADMINISTRATION

| | | Fluid Intake | | | | | |
|---|---|---|---|---|---|---|---|
| Day | Urine Output Cc. | Blood Cc. | Plasma Cc. | 25% Albumin Cc. | Water Cc. | Dextrose in Water % | Fluid Removed from Left Chest Cc. |
| 0 | 0 | 500 | | | 1500 | 5 | ± 300 |
| 1 | 80 | 500 | | | 2000 | 5 | |
| 2 | 50 | 1000 | | | 2000 | 10 | |
| 3 | 30 | 500 | | | 2600 | 5 | 2000 |
| 4 | 60 | 500 | | | 2000 | 15 | 1000 |
| 5 | ±60 | | 600 | | 1500 | 10 | |
| 6 | ±60 | | | 50 | 800 | 30 | 300* |
| 7 | ±60 | | | | | | |

* 300 cc. venesection.

TABLE VII

CASE 4: URINE ANALYSIS

| Day | N.P.N. Mg. % | Urea N Mg. % | $NH^3$ N Mg. % | Creatine Mg. % | Creatinine Mg. % | Gross and Microscopic Appearance |
|---|---|---|---|---|---|---|
| 2 | 410 | 128 | | | | Black, turbid, loaded with débris; no casts or R.B.C. |
| 3 | | 70 | 55 | | | |
| 4 | 410 | 95 | | 0 | 24 | Dark brown, clear |
| 5 | | 40 | 0 | | | |
| 6 | 92 | 29 | | 0 | 24 | Amber, clear, acid, albumin 4+; many R.B.C. |

TABLE VIII

CASE 4: UREA REMOVAL BY PERITONEAL IRRIGATION

| | Peritoneal Fluid | | | | Blood Urea Clearance |
|---|---|---|---|---|---|
| Day | Volume Cc. | Flow Rate Cc./Min. | Urea N Mg. % | Total Urea Gm. | by Peritoneum Cc./Min. |
| 2 | 38,000 | 26.5 | 23.3 | 17.7 | 7.6 |
| 3 | 38,000 | 26.5 | 20.6 | 15.7 | 7.9 |
| 2 | 34,000 | 23.6 | 21.0 | 14.3 | 9.7 |
| 9 | 18,000 | 16.6 | 34.0 | 12.3 | 12.5 |

It is difficult to predict the exact state of affairs with reference to excretion and absorption across the peritoneal membrane with the type of irrigating fluid used and a varying state of hydration of the plasma and extracellular fluids. It is not known whether, with the type of fluid used, irrigation offers a route of exit for excess body water. We suspect that

the fluid as at present constituted is not satisfactory for this purpose. Experience with Case 4 indicates that when the peritoneal fluid is made hypertonic by 5 per cent gelatin and 2.5 per cent glucose, water can be so rapidly removed from the plasma that caution should be exercised to avoid excessive hemoconcentration. Eventually it may prove desirable to modify the electrolyte composition of the irrigating fluid, for better control of acidosis by reducing the chloride content to that of normal plasma and substituting sodium lactate buffered with lactic acid. Further, an increase in the glucose of the irrigation fluid might provide a sufficient amount to balance what is lost into the peritoneal fluid from the intravenously administered glucose, to counteract water absorption from the irrigating fluid and to provide some of the glucose for metabolic needs. If modifications needed for such purposes result in making the fluid hypertonic, their long-continued use might be impractical, because of the potentially irritating properties of such solutions. Further data will be accumulated to discover the optimal solution under most circumstances.*

The proper time to institute peritoneal irrigation is not established. It is not possible to say when any given data regarding the uremic state signify the existence of irreversible damage. Therefore, since the method can be carried on for many days safely it should be started soon after the uremia is full-blown. Meanwhile it is important not to add to the patient's burden by the harmful effects of excessive water administration, since the amount of water needed is small and as a diuretic it is futile. The time for discontinuing peritoneal irrigation can be determined readily by measurements of the return of sufficient kidney function to prevent azotemia and to sustain a normal fluid and electrolyte balance.

## CONCLUSIONS

1. Continuous peritoneal irrigation with an appropriate fluid is a satisfactory method of eliminating uremia. It can be used in any case of acute renal failure in which death from uremia is likely and in which recovery of kidney function is considered possible.

2. The control of fluid and electrolyte balance is at least as important as the elimination of nitrogenous waste products, and is an integral part of this therapeutic method.

* Since submitting this article for publication additional clinical experience (to be published) has demonstrated that the use of 2% glucose in the irrigating fluid instead of glucose at blood level concentration will prevent the production of edema from the absorption of water from the irrigating fluid. Furthermore, the absorption of glucose from 35 liters of such irrigating fluid in 24 hours was found to be some 200–300 grams of glucose. The absorbed glucose therefore reduces the basal requirement of a starving patient from 400 to 100–200 grams per 24 hours, and so reduces the amount that must be administered intravenously to prevent starvation acidosis. Two per cent glucose, moreover, is not irritating to the peritoneum.

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DISCUSSION.—DR. ARTHUR B. MCGRAW, Grosse Pointe, Mich.: I wish to add a very incomplete report on one patient, upon whom an attempt was made to use this method of Doctor Fine's. Five days before this meeting, our Pediatric Department asked me to help them set up an irrigation system such as Doctor Fine describes. We had no sump-tube of the size described by him, but we did have one small abdominal suction tube of brass, chrome plated and rather worn. We cut it down to what we felt was the proper size.

The patient was an anemic anuric six-year-old boy, suffering from glomerulonephritis superimposed on a severe nephrosis. It worked very well for one day and night, and the next day. On the third day we had a little trouble with the outflow of the tube and I think that in trying to wipe that out we may have introduced contamination into the peritoneal cavity. On the fourth day it stopped, and when I left we had decided to take it out, leave it out overnight, and then reinsert it in another location. I can only report that the child's nonprotein nitrogen dropped progressively in four days from 150 to 95. I think this is an interesting method, and it holds great promise. If we try it again with more precautions and more careful teamwork, I believe we can achieve successes such as Doctor Fine reports.

DR. EDWARD D. CHURCHILL, Boston, Mass.: The type of case selected by Doctor Fine for experimental observations tends to obscure the broad surgical application of such a method when it is perfected and ready for general clinical application. It may not be realized that, despite all the optimistic reports on the successful management of shock in this war, renal shutdown was the stone wall against which we butted our heads many times. The reduced blood volume of shock could be corrected by transfusion, but the kidneys ceased to function and many wounded men died despite the most skilled surgical procedures. The full explanation is still not clarified; the problem requires further study. The surgeons caring for these patients with anuria tried many forms of treatment: high spinal anesthesia; alkalies, to the point of severe alkalosis; and many other measures. Still the patients died in uremia. Doctor Fine's method represents one more procedure that may be applicable to men suffering from renal shutdown following severe trauma. I hope it will prove successful.

DR. ALLEN O. WHIPPLE, New York City: I have been tremendously interested in this new experimental work. Doctor Fine told me about it a few days ago, and I think he has established a point of departure in the treatment of anuria and uremia which will apply not only to surgical but to medical cases, and is a real advance. One

point he has emphasized is the difficulty of maintaining an adequate system of intake and output in the peritoneum. The peritoneum, fortunately, has the greatest capacity for obstructing anything you put into it and shutting it off, of any tissue in the body. We have been interested in this problem in patients with ascites, in an attempt to shunt the fluid into the ureter, and our problem has been that of preventing the peritoneum from shutting off any anastomosis we made. We have not succeeded as yet in devising any method to avoid blocking and plugging of any apparatus we have introduced into the ureter.

DR. ALTON OCHSNER, New Orleans, La.: Some of the original work on this problem was done by Sidney Bliss. About 15 years ago he showed that a bilateral nephrectomy could be kept alive with normal urea content of blood for many weeks. He showed also that much less effectively this could be accomplished by gastric lavage. We have had two patients who had almost complete renal shutdown due to incompatible blood. One was a young woman in whom the reaction was not recognized for 26 hours after transfusion. The nonprotein nitrogen started to go up—to 190. She was started on gastric lavage, using as much as 20 liters of fluid in the 24 hours, and it was brought down to less than 70 and maintained at that level until the urinary function returned.

The other patient, a man, also had an incompatible blood reaction; he had a bad kidney function to begin with. He was treated with gastric lavage with large amounts of fluid. The first case required about two weeks and the second ten days. We have been afraid of peritoneal lavage, and I believe the same results can be obtained by gastric lavage if large amounts of fluid are used.

DR. JONATHAN E. RHOADS, Philadelphia, Pa.: We approached this problem in a much less thorough manner in 1938, in two patients, introducing fluid, a liter at a time, through a cannula into the peritoneal cavity. Large amounts of urea were recovered in the solution when it was allowed to drain out. In reviewing the literature it was found that substitution methods of treating renal failure go back to 1913, when Abel, Rowntree and Turner set up a system of celloidin tubes through which the blood of animals was circulated. A further study was made in Germany by Haas, and Gantner suggested the use of the peritoneal lining as a dialyzing membrane. His experiments were successful chemically, but, in general, the patients in which the method was used were not capable of recovery.

It is now easier to employ the method of Abel, Rowntree and Turner, because suitable tubes for dialysis can be obtained in the form of sausage casing, which is available in lengths of 100 feet. About two years ago Dr. Henry Saltonstall and I set up a system using 60 feet of this tubing in a bath of Ringer's solution with sufficient gelatin to counteract the osmotic pressure of the serum proteins, and by heparinizing the patient it was possible to allow his blood to flow out from an artery through this system and to reënter the circulation through the veins. This method, too, will reduce the urea nitrogen.

DR. RALPH COLP, New York City: The method which Doctor Rhoads has described was the subject of a thesis by Doctor Kolff of Amsterdam, Holland, published in January, 1946. I have an abstract of it prepared by Dr. I. Snapper, and I think that some of the pictures might clarify some of the statements Doctor Rhoads has made. (slide)

"Doctor Kolff emphasizes that the construction of an efficient artificial kidney has only been possible since an efficient anticoagulant, heparin, and a good dialyzer consisting of a cellophane tube, 23-mm. wide and 50 yards long, have become available. The cellophane tube is wound spirally around a cylinder which consists of a wooden lattice with a coat of lacquer (Fig. 1). This cylinder rotates slowly and the lowest part of the cylinder is submerged in a tank (Fig. 2) containing 70–100 liters of a

solution of 0.6% NaCl, 0.2% $NaHCO_3$, 0.04% KCL and 1.5 to 2% glucose. A glass cannula is tied into a vein on the dorsum of the foot, or in the forearm, and a slow infusion of salt solution is started. Then another glass cannula is tied into the radial artery. After this, the patient is heparinized with 1,200 milligrams of heparin or more. The glass cannula in the artery is connected by a rubber tube with the cellophane tube. As the cylinder is turned continuously after it has migrated through the entire length of the cellophane tube, it is transported *via* another rubber tube to which a small pump has been attached to the cannula which has been tied in the vein.

"The cellophane tube is only partially filled with blood, so that the blood is spread over a large surface which greatly increases the rate of dialysis. During the passage of the blood through the cellophane tube, large amounts of crystalloid substances of the blood are removed by dialysis. Since no calcium can be present because of the $NaHCO_3$ content in the fluid against which the blood is dialyzed, calcium is also removed from the blood. It is, therefore, necessary to give one or two intravenous injections of calcium gluconate to the patient slurring the dialysis.

"The dialysis lasts 10–14 hours. After the dialysis is finished, the cannulas in artery and vein are closed off and left *in situ* for 24 hours. When the coagulation time of the blood has returned to normal, the cannulas may be removed. The salutary effect of the vividialysis in the artificial kidney is demonstrated by the amount of urea which is removed from the blood during this period. The largest quantity of urea dialyzed out amounted to 260 Gm. Even in cases in which the blood urea nitrogen before dialysis had risen to 160 mg. per cent, one dialysis was sufficient to reduce this value to 45 mg. per cent. At the same time the increased nonprotein nitrogen, uric acid, creatinin and indoxyl of the blood fell to nearly normal values, and the xanthroprotein reaction of the serum diminished significantly. Clinical signs of uremia usually disappeared within 24 hours. It is evident that the artificial kidney will only have a temporary effect in patients with chronic nephritis and uremia. However, in instances in which an individual with previously competent kidneys suddenly develops loss of renal function, the artificial kidney may well have a life-saving action. Kolff cites two cases in which survival of the patient has at least been due to the purification of the blood in the artificial kidney."

Dr. Jacob Fine, Boston, Mass. (closing): I am very grateful for this discussion. Some of the points brought up are dealt with in the body of the paper. I should like to underline Doctor Churchill's warning that this is still a highly experimental phase of the problem and is not presented as a satisfactory clinical method as yet. The method of external dialysis might prove satisfactory. Our objection to it is that it imposes an arteriovenous anastomosis on an already seriously ill patient. Continuous irrigation of the gastroduodenal tract will remove some excretory products. It is our view that not enough will be removed by this route to cure azotemia or restore electrolyte balance in persistent and total renal suppression.

Doctor Whipple referred to the difficulty with plugging of the tubes. We have fully obviated this with the stainless steel sump-drain for drainage. The inlet catheter, so far in our experience, has not plugged so long as fluid is kept running in. Irrigation proceeded smoothly with the sump-drain in the last two patients, in one for seven and in the other for six days without discomfort. The tube should be directed down into the cul-de-sac. The drainage fluid must be watched to see when bacteria first appear, so as to introduce appropriate chemotherapy if needed.

I have nothing to add in reference to Doctor McGraw's experience with the child with nephrosis. If there is some likelihood that the renal lesion is reversible in a few weeks' time, we believe this method will be advantageous, but we are not prepared to say whether any form of nephritis or nephrosis is suitable. In renal injury from incompatible blood, the method keeps the patient free of uremia during the period of shutdown and may shorten the time of healing and recovery of renal function.

# THE SURGICAL TREATMENT OF CONGENITAL PULMONIC STENOSIS*

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PRIOR TO THE INITIATION[1] of the work to be discussed in this paper only one attempt had been made by operative means to treat patients with pulmonic stenosis. This attempt was made by Doyen[2] in 1911, the procedure consisting of division of the constricted area with a tenotome knife. The patient died shortly after operation. In patients with congenital pulmonic stenosis the constricted or atretic area is usually not in the valve but is in the pulmonary conus itself. It is doubtful if incision or partial excision of the stenotic area would result in permanent improvement; it appears likely that the area would subsequently become stenosed again. These considerations led to an attempt to treat the condition by a different type of operation.

Many experiments[3, 4] preceded the first attempt to increase the pulmonary blood flow of patients. It was demonstrated first that one can anastomose without great risk the end of one of the arteries arising from the arch of the aorta to the side or to the distal end of one of the two pulmonary arteries of anesthetized dogs. In subsequent experiments, after a high degree of chronic arterial unsaturation had been produced, it was found that the creation of an artificial ductus arteriosus resulted in an elevation in the oxygen saturation of arterial blood.

When the problem was transferred from the experimental animal to the patient, it was thought that a moderate degree of improvement would result in the patient with pulmonic stenosis if the pulmonary blood flow were increased. The improvement in most cases has been much more striking than had been anticipated. Some of the results will be described later in this paper.

The main indication for operation is evidence of an inadequate flow of blood to the lungs. Important in the diagnosis is the absence of visible pulsations in the lung fields as observed under the fluoroscope and roentgenographic evidence that the pulmonary artery is small in size. The typical case of the "tetralogy of Fallot" should not present great difficulties in diagnosis. There are, however, many borderline cases in which it is difficult or impossible to be certain of the true nature of the condition. If under such circumstances the patient has a hopeless prognosis without an operation, Dr. Taussig and I have taken the position that an exploration is indicated. If doubt still exists after the pulmonary artery is exposed, the pressure in the artery is measured by using a needle and a water manometer. When the pressure is greater than 300 mm. of water, it is our opinion at present that an anastomosis is probably inadvisable.

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

The limits as to age-groups suitable for the operation have not been established. The operation has been performed successfully on an infant of five months and on an adult of 21 years. The operation was attempted on an infant two months of age, but there was atresia of the pulmonary orifice and the artery was diminutive in size, and an anastomosis could not be performed. It is believed that the age-period of two years to ten years is the most desirable one in which to perform the operation.

Although most of the children have had visible cyanosis when at rest, one should not be misled by the absence of cyanosis if the patient has little or no tolerance to exercise. Under such circumstances the arterial oxygen saturation should be determined under basal conditions and immediately following exercise. If there is definite decrease in the saturation with exercise and if inadequate pulmonary blood flow is believed to be the cause, an operation should be seriously considered. Several of our most gratifying results have been in patients of this type.

There have been a few alterations in operative technic during the past year. Probably the greatest has been in connection with the side of the chest on which the operation is performed. It was held originally that the approach should be made on the left if one wishes to utilize a subclavian artery for the anastomosis. This view has been altered, and it is believed now that one should make the approach on the side on which the innominate is located. This is usually, but not always, the right side. If the aorta descends on the right, the innominate artery is located on the left rather than the right. Such has been the position in more than 20 of our patients. Fortunately the position of the aorta can be determined preoperatively by employing the method of Bedford and Parkinson.[5] If one makes the approach on the side on which the innominate artery is located, one may choose the innominate artery, the subclavian artery, or the carotid artery for the anastomosis depending upon the existing inadequacy of the flow of blood to the lungs and the sizes of the available vessels. The choice of vessels is not always an entirely free one because in some instances the innominate or the subclavian artery may be too short for the desired purpose and the longer vessel must be chosen. Exposure of the innominate artery not only offers a wider choice of vessels but is of advantage in case the subclavian artery is used. After an anastomosis in which the subclavian branch of the innominate is used, the subclavian artery makes an angle of approximately 90 degrees with its parent vessel. The angle is usually a much more acute one when the subclavian branch of the aorta is used. The use of the subclavian branch of the innominate is demonstrated in Figures 1 and 2.

There has been a wide variation in arteries arising from the arch of the aorta. In some instances the four arteries have arisen independently, there being no innominate artery. In several cases the right subclavian artery has arisen on the left and has reached the right arm after passing under the trachea and esophagus. Despite the multiplicity of variations there has been in every case a systemic artery which was suitable for anastomosis to a pulmonary artery.

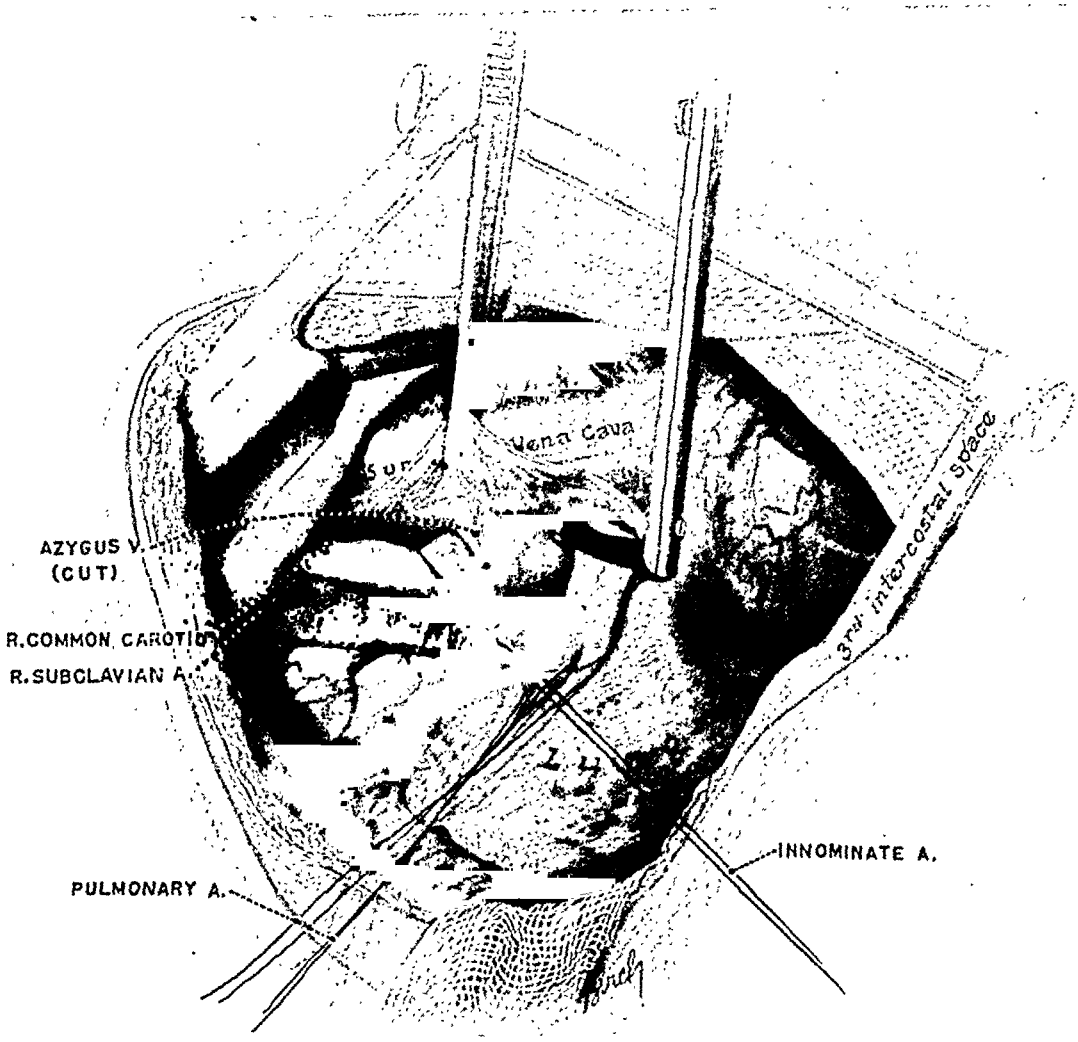



FIG. 1.—Showing the right pulmonary artery, the innominate artery, the right common carotid artery and the right subclavian artery prior to ligation and division.

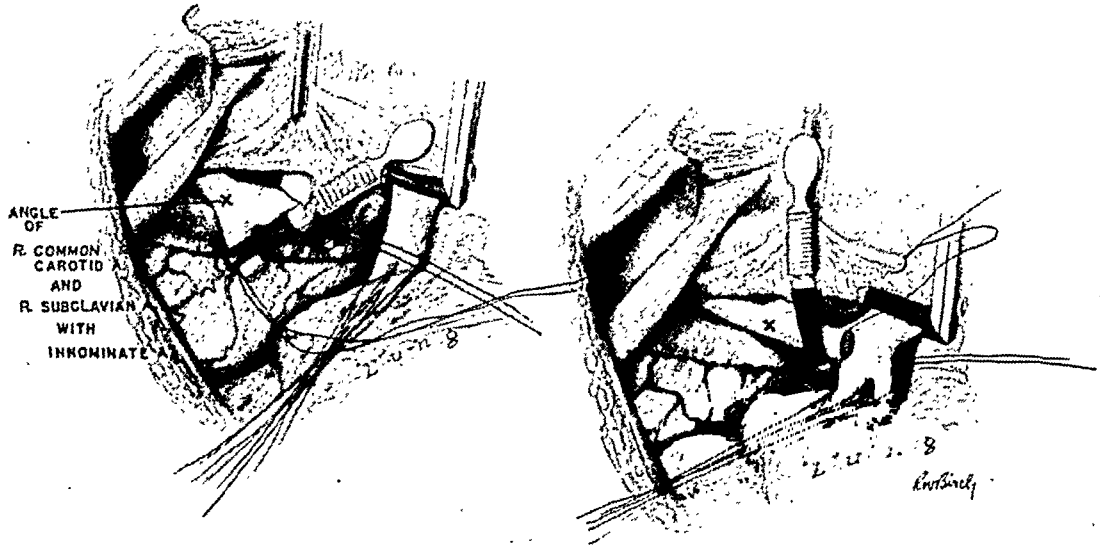



FIG. 2.—Showing the anastomosis of the proximal end of the right subclavian artery with the side of the right pulmonary artery. The transposed subclavian artery makes an angle of approximately 90 degrees with its parent vessel.

Variations in the position and size of the pulmonary artery have been fewer than was anticipated. In one patient the right pulmonary artery could not be found at the time of operation and was located with difficulty at autopsy. It was small and was inferior and posterior to its usual position. In another case the pulmonary artery was lying inferior and posterior to the superior pulmonary vein. Unfortunately, the vein was mistaken for the artery and the anastomosis was performed. Death occurred a short time after operation. In a third patient, an infant of two months with atresia of the pulmonary orifice, the right pulmonary artery was diminutive in size. The lumen of this vessel was only about one-tenth the size of that of the subclavian artery and a satisfactory anastomosis could not be performed. In a number of cases the right main pulmonary artery has been very short because of early branching. In two of the earlier operations the branch to the right upper lobe was mistaken for the main right pulmonary artery. In an occasional case in which the main right pulmonary artery is very short it may be necessary to ligate and divide the vessel and to use the distal end for an anastomosis to the end of the systemic artery. If, however, the pulmonary artery is freed of its pericardial attachments, this procedure will very rarely be necessary.

In evaluating the alterations in the oxygen saturation of arterial blood which result from the operation one should bear in mind that in addition to pulmonary stenosis or atresia, patients with the tetralogy of Fallot have an interventricular septal defect and an aorta which communicates with both ventricles. In other words, the aorta probably always receives some venous blood as well as arterial blood, and one would not expect the arterial blood to reach the normal saturation of 95 per cent, or greater, even when the pulmonary blood flow is definitely increased by the creation of an artificial ductus. In view of the septal defect and the overriding aorta it is rather surprising that the arterial saturation has risen so greatly in many of the patients. Some of the more striking results of the operation are shown in Table I.

The improvement in the general condition of the patients has paralleled the alterations in the saturation of the blood and the decrease in the polycythemia. A change in the color of the mucous membranes is usually apparent shortly after completion of the operation. Cyanosis of the nail beds disappears more slowly and the regression or disappearance of clubbing of fingers and toes requires still longer. A number of the children who could walk only a few feet prior to the operation can now walk a mile or more. Some of the children engage in fairly strenuous exercise.

Operation has been performed upon a total of 110 patients. This figure includes all patients upon whom an incision was made and hence some in whom an anastomosis was not performed. With one exception all operations were performed during the last 14 months. A total of 25 patients have died, making an over-all mortality rate of 23 per cent. A more detailed analysis follows.

In the 110 operations an anastomosis was performed between the end of a systemic vessel and the side of one of the two pulmonary arteries in 91

TABLE I

THE EFFECTS OF AN ARTIFICIAL DUCTUS ARTERIOSUS IN THE TREATMENT OF PULMONIC STENOSIS

| Systemic Artery Used | Patient | Age | Art. Saturation Per Cent | | Red Blood Cell Count | | Hematocrit Reading (Wintrobe) | | Result |
|---|---|---|---|---|---|---|---|---|---|
| | | | Preop. | Postop. (Time After) | Preop. | Postop. (Time After) | Preop. | Postop. (Time After) | |
| | | | | (111 days) | | (111 days) | | (111 days) | |
| Innominate | A. B. | 2 | 28.1 | 85.3 (55 days) | 5,640,000 | 4,620,000 (55 days) | 57.5 | 38.6 (13 days) | Good |
| Innominate | J. B. | 3 | 45.9 | 74.3 (19 days) | 7,530,000 | 5,300,000 (19 days) | 68.0 | 56.0 (19 days) | Good |
| Innominate | C. C. | 4 | 35.6 | 77.1 (20 days) | 9,630,000 | 6,170,000 (20 days) | 82.0 | 55.2 (20 days) | Good |
| Innominate | M. E. | 26 Mos. | 29.9 | 71.9 (17 days) | 10,010,000 | 5,950,000 (17 days) | 64.3 | 46.2 (17 days) | Good |
| Innominate | R. L. | 6 | 22.1 | 74.8 (2.5 mos.) | 11,260,000 | 6,870,000 (2.5 mos.) | 73.2 | 57.0 (2.5 mos.) | Good |
| Innominate | M. M. | 6 | 23.4 | 83.7 (5 mos.) | 10,120,000 | 5,600,000 (5 mos.) | 81.0 | 38.0 (5 mos.) | Good |
| Innominate | B. R. | 12 | 36.3 | 86.7 (3.5 mos.) | 7,660,000 | 4,980,000 (3.5 mos.) | 71.0 | 50.0 (3.5 mos.) | Good |
| Innominate | L. S. | 6 | 38.6 | 89.9 (20 days) | 9,970,000 | 4,640,000 (20 days) | 81.0 | 46.0 (20 days) | Good |
| Innominate | B. S. | 2 | 34.0 | 73.2 (15 days) | 9,680,000 | 7,530,000 (15 days) | 72.2 | 50.2 (15 days) | Good |
| Carotid | R. L. | 3 | 26.1 | 81.9 (61 days) | 9,080,000 | 5,200,000 (61 days) | 62.4 | 50.0 (61 days) | Good |
| Subclavian | S. B. | 21 | 57.7 | 83.7 (18 days) | 7,960,000 | 6,580,000 (18 days) | 81.2 | 62.5 (18 days) | Good |
| Subclavian | R. H. | 3 | 32.7 | 74.0 (4 mos.) | 5,660,000 | 5,340,000 (4 mos.) | 58.0 | 50.5 (4 mos.) | Good |
| Subclavian | W. L. | 3 | 65.6 | 84.3 (3 mos.) | 6,390,000 | 4,610,000 (3 mos.) | 57.0 | 41.8 (3 mos.) | Good |
| Subclavian | S. V. H. | 7 | 49.3 | 81.1 (35 days) | 8,160,000 | 6,050,000 (35 days) | 78.8 | 56.5 (35 days) | Good |
| Subclavian | C. W. | 3 | 39.3 | 75.7 | 7,480,000 | 6,690,000 | 77.0 | 64.3 | Good |

patients. There were 16 deaths in this group, a mortality rate of 18 per cent. The subclavian artery was used in 46 patients, with four deaths. One of these was due to hemoptysis on the fifth day which was believed to have been caused by the use of dicumarol. The innominate artery was used in 36 patients and there were 11 deaths in this group. One of these patients was found at autopsy to have a single ventricle with insignificant pulmonary stenosis and another had a transposition of the great vessels which was combined with pulmonary stenosis. The commonest cause of death in this group was cerebral anemia or thrombosis. The end of the carotid was anastomosed to the side of one of the pulmonary arteries in nine patients. There was one death in this group, which occurred nine months after operation. Anastomosis had been performed despite the fact that the patient had a large pulmonary artery with vigorous pulsations. It is believed that this patient had the Eisenmenger complex.

An end-to-end anastomosis was attempted between the end of a systemic artery and the end of one of the two pulmonary arteries in ten patients. This method was used because the pulmonary artery was very short or small or because the patient was extremely ill and haste was necessary. There were four deaths in this series. These four patients had atresia of the pulmonary

orifice and the vessel was too small for a satisfactory anastomosis. In the future an attempt will be made under such conditions to perform the anastomosis between the end of the systemic vessel and a longitudinal opening in the side of the pulmonary artery.

In two patients the right main pulmonary artery was very short and the branch to the upper lobe was mistaken for the main vessel. The subclavian artery was anastomosed to the end of the small artery to the upper lobe. Both of these patients died. In retrospect, it is apparent that the main right pulmonary artery might have been divided and its distal end used for the anastomosis if the condition had been recognized.

Anastomosis was not performed in six patients. In four of these the pulmonary arterial pressure was high and it was thought that anastomosis was not indicated. These patients survived the exploratory operation. The remaining two patients died. In one of these the pulmonary artery was not found at operation and it was located with difficulty at the time of autopsy since it was small and in an abnormal position. In a second patient the chest was simply opened and closed because it was apparent that the patient would not withstand the operation.

In the remaining patient of those who died the right pulmonary artery was inferior and posterior to the superior pulmonary vein. The vein was mistaken for the artery and its side was anastomosed to the end of the carotid artery. The patient died shortly after completion of the operation.

It is of interest that none of the patients had empyema or mediastinitis. Severe bleeding from the anastomosis did not occur postoperatively in any case. There was no significant interference with the circulation of the arm on the side on which the subclavian artery was sacrificed or used for the anastomosis in any of the patients. Weakness or paralysis of the opposite side of the body in patients in whom the innominate or carotid artery was used either had cleared or was diminishing in all who survived the operation.

Although some of the operations were performed too recently to allow an evaluation, it appears that all of the patients with one exception who have survived the performance of an anastomosis are improved. The subclavian artery of this patient was injured by the too vigorous application of the constricting device, and it is probable that thrombosis occurred. It is believed that the artificial ductus in the remaining patients is patent although a murmur cannot be heard in at least one of them. Heart failure or *Streptococcus viridans* endarteritis has not developed thus far in any of the patients.

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DISCUSSION.—DR. ALLEN O. WHIPPLE, New York City: It is a privilege for me to pay tribute to this magnificent presentation and to the outstanding leader in the new field of surgery of shunting operations, and I cannot express this too strongly. There is one matter I want to mention, that is, the very interesting opportunity for studying the physiology of the patient with the shunting operation; whether they be cardiovascular, or whether they be thoracic or abdominal. It is a new field, one in which the disarranged physiology, in many instances total disability, is altered immediately by the shunting procedure, and I am sure that in the future this field will be explored extensively; but we shall always look back, those who have seen this, to this very remarkable presentation today.

DR. CLAUDE S. BECK, Cleveland, Ohio: I should like to congratulate Doctor Blalock and Doctor Taussig on this work. I have been trying to think of something in the surgical literature that might be related to this operation. The only suggestion that has any similarity to this operation was published by Jeger.* He proposed an operation for aortic stenosis consisting of anastomosis of the severed proximal end of the innominate artery to the cavity of the left ventricle, using a segment of jugular vein to connect these two structures. He also proposed an operation for mitral stenosis consisting of anastomosis of the distal end of a severed pulmonary vein to the cavity of the left ventricle using a segment of jugular vein to connect these two structures. These proposals were not applied to patients. The Blalock-Taussig operation is original in its conception. It was worked out in the experimental laboratory and, finally, it was applied to patients. The operation does not cure this cardiac abnormality. The circulation is not restored to normal. It provides definite benefit. I think it is one of the nicest contributions to surgery made in my lifetime.

Cardiovascular disease, in general, is responsible for about one death in three. This is the most important group of diseases that the physician treats, and yet the physician who treats diseases of the heart and blood vessels seldom if ever sees these organs in the living patient. We know that direct vision and direct manipulation can contribute to knowledge and understanding such as cannot be accomplished by any of the indirect methods of approach. I believe that progress in this field will be made by the direct approach to these structures. The Blalock-Taussig operation is based upon direct approach. There are funds available for cardiovascular research, and I hope that the internists who have charge of these funds will not forget that the direct surgical approach has something to offer and that surgical exploration should be encouraged.

DR. ELLIOTT C. CUTLER, Boston, Mass.: I rise to add my congratulations to the authors of the present paper. About 22 years ago, in a rather bungling fashion, I presented a direct attack upon the stenosed mitral valve. In the intervening time a great many signposts have been laid down making cardiac surgery far more safe than it was in those days. I have watched the work of Robert Gross, who first successfully accomplished the ligation of the patent ductus arteriosus. This new procedure in the field of cardiac surgery for children with other congenital lesions offers great stimulation to those who work in the field of cardiac surgery, and we are indebted to Doctor Blalock for his magnificent contribution.

*Jeger, Ernst: Die Chirurgie der Blutgefässe und des Herzens, Berlin, Hirschwald, 1913.

DR. RUDOLPH MATAS, New Orleans, La.: No one who has kept in touch with the marvelous progress of cardiac surgery and heard Doctor Blalock's account of his latest contribution on pulmonary stenosis and atresia can doubt that a new and unique chapter in the surgery of congenital cardiac defects has materialized. What a few years ago were fantastic speculations of laboratory workers have now become actual living and working realities. It would now seem plain that on the basis of the advances already accomplished, the surgery of the intrathoracic cardiovascular defects should be divided into (1) operations for the cure of the teratologic or congenital defects or deformities, such as patent ductus arteriosus, coarctation of the aorta and stenosis or atresia of the pulmonary artery, in which the names of Monro, Gross, Crafoord and Blalock should remain inscribed as those of pioneer founders and inspirers. In a second group, much larger and older, we should include the operations for acquired postnatal cardiovascular diseases and defects that are amenable to surgery, such as pulmonary embolectomy, cardiorraphies for traumatisms, extraction of foreign bodies, concretio or constrictio pericardi, valvulotomies for mitral and aortic stenosis, surgical treatment of coronary disease by the various methods of improving the coronary circulation, *etc.*, the excision of aneurysms from the aorta and heart itself, and still other recent achievements for acquired or pathogenic cardiac defects, the treatment of which has crowded the pages of contemporary history with the names of surgeons whose achievements here and abroad make us proud of our Science and of our Art.

Doctor Blalock's experience and magnificent success in the surgical cure of pulmonary and aortic congenital strictures are very striking from the purely technical point of view alone; his fine, finished needle work in establishing lateral and circular anastomoses between the aortic and pulmonary branches is a bit of artistry that undoubtedly contributes to the success of his work. It is impressive to note how the children who are disabled by their congenital cardiac defects sustain and survive the operations so much better than the normal dogs operated upon with the same care and technic in the experimental laboratory. It is also impressive to note how effectively the collateral circulation is spontaneously developed in the stenotic child, whether of pulmonary or aortic type. The difference in favor of the child being that in the child the collateral circulation has had a chance to adapt itself to its obstructive defect while in the dog it has not. It is also impressive to note that in these defective children the great arteries, aorta, innominate, subclavians, axillaries, can be ligated and divided and transplanted with an impunity inconceivable in normal children and adults. The carotid alone, seemingly resents interference with its function, by exhibiting secondary brain complications which spoil the results of operation that would otherwise be successful in the other arteries. The success of the work of Doctors Blalock and Taussig will undoubtedly give a great impetus to the surgery of cardiovascular teratology; and Doctor Taussig's noted skill in the differential diagnosis of these congenital defects will create a new interest in pediatricians and cardiologists which will soon be reflected in the rising statistics of the new surgery.

DR. EMILE HOLMAN, San Francisco, Calif.: I should like to report our experience in two attempts. After operating upon 15 dogs and succeeding in half of them, we thought we were equipped to do the operation according to Doctor Blalock's technic. The first patient was 18 months old, had a hemoglobin of 182 per cent, and syrupy blood. The distance between the subclavian vessel and the pulmonary artery was so long that after we had anastomosed them there was an acute angle which interfered with proper flow. The baby expired the next day. In this case we were confronted with a remarkable collateral circulation over the mediastinum. We also noted after operation that this baby had a completely lifeless arm. We had to divide many vessels to get enough length of artery for anastomosis. In the next attempt, a five-year-old child, we avoided the subclavian artery, made an incision in the neck where

the common carotid was divided and brought down to the pulmonary artery. She has done fairly well. On the fifth day there developed hemiplegia on the left side, which was complete, and was interpreted as an embolic lesion in the internal capsule rather than thrombosis of the vessel we had divided. This has gradually improved and there is only a small residual weakness in the left arm. Again, in this second instance, the blood was exceedingly thick, and I would like to have Doctor Blalock tell us what he does to improve the condition of the blood both before and after operation.

May I, too, express my admiration for this brilliantly conceived surgical procedure, which is both breath-giving and breath-taking.

DR. ALFRED BLALOCK, Baltimore, Md. (closing): I wish to thank Doctors Whipple, Beck, Cutler, Matas and Holman. I would like to echo what Doctor Matas said about Doctor Cutler. He certainly has had a great deal to do with paving the way for subsequent advances that have been made.

Doctor Matas spoke of collateral circulation. It is quite true that in some instances all the blood to the lung goes through collateral vessels; in patients with atresia the bronchial vessels are enlarged and other vessels also contribute in carrying blood to the lung.

It is true, as Doctor Holman said, that the blood in practically all these individuals is thick; the red count may be eight, ten or 12 million; hematocrit readings as high as 95 per cent. I do not think anything should be done about that preoperatively. If a great deal of blood is lost during operation I am confident that no blood should be removed after operation, but if the operation is bloodless, to the extent that only a little is lost, we usually remove blood at the completion of the operation. We have had no difficulty with the arm on the side on which we have ligated the subclavian artery, and we have had about 90 such patients. On the other hand, we have had patients who developed cerebral ischemia or thrombosis, and I think most deaths are on that basis. We had several patients who developed weakness on the opposite side of the body, but in all those who survived, it has either cleared completely or is clearing.

Regarding the use of the carotid, it is the easiest vessel to use, but I think one should employ it only in exceptional circumstances, because if the subclavian is not big enough one should choose the biggest vessel available, the innominate. The carotid can be approached through the chest, and it is not necessary to expose it in the neck.

I want you to realize that all these operations have been undertaken in a relatively short period of time. We can make no predictions as to the condition of these patients some years hence.

I would like to acknowledge the important part Dr. Helen Taussig has played in this work, also the important rôles of Dr. Austin Lamont and Dr. Merel Harmel, who anesthetized the patients.

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# ARTERIAL REPAIR IN THE TREATMENT OF ANEURYSMS AND ARTERIOVENOUS FISTULAE*

## A REPORT OF EIGHTEEN SUCCESSFUL RESTORATIONS

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THE INCIDENCE OF GANGRENE due to acute ischemia following operations on aneurysms and arteriovenous fistulae is rare. Not a single instance occurred in 100 cases operated upon at DeWitt General Hospital. There was but one case in the entire series of patients in the three Vascular Centers of the U. S. Army. This splendid record is probably due both to the policy of waiting a sufficient length of time for the development of collateral circulation and to the perfection of surgical technic in order to spare the important collaterals. In addition, prophylactic sympathectomy may have helped practically to abolish gangrene after operations on arterial lesions.

Although there is sufficient circulation to care for the metabolic needs of the tissues at rest, interruption of the major artery to a limb may lead to persistent symptoms of impaired circulation. Makins[1] has emphasized the degree of disability which frequently ensues. Bigger[2] has reported that "in the patients in whom a main vessel was resected for arteriovenous fistula there was no instance of serious acute circulatory difficulty, but all of them have evidence of persistent circulatory deficiency." Because of residual symptoms of inadequate circulation following excision of aneurysms and arteriovenous fistulae sympathectomy was subsequently performed in 29 patients at one of the Vascular Centers. Although improvement was noted in the cases there was generally some residual impairment of function.

Restoration of the circulation through the damaged artery as the ideal method of treatment was recommended by Matas.[3] In the treatment of arterial aneurysms he suggested either restorative aneurysmorrhaphy in cases where the defect in the arterial wall was small or the reconstructive operation in the presence of large defects. Bickham[4] subsequently applied the Matas technic of intravascular repair to the treatment of arteriovenous fistulae. He was the first to suggest the transvenous closure of the defect in the arterial wall with preservation of the continuity of both artery and vein.

Preservation of the artery is not without its hazards. Even though the arterial repair is successful, the possibility of subsequent formation of a false aneurysm, especially in the presence of degenerated arterial wall, has been held to contraindicate the use of this technic. Reid[5] has stated "the development of an abundant collateral blood supply makes the operation unnecessary. It is doubtful if the badly degenerated artery should be restored to normal function." Bigger[2] also has emphasized the point that "the most important contra-

*Read before the American Surgical Association, April 2-4, 1946, Hot Springs, Virginia.

† From Dept. Surgery, University of California Medical School, San Francisco, Calif.

indication to arterial suture is calcification of the wall of the artery in the area to be sutured." Complications from recurrence of aneurysms following restoration of the continuity of the artery have been reported by Bigger,[2] Reid,[6] and Pemberton and Black.[7] Objection to the transvenous method of closure is based on the fact that an additional opening or weak point in the arterial wall may be overlooked. Reid and McGuire[8] have reported one example of this nature, and Holman[9] has observed another. On several occasions we have noted that both the accompanying veins communicated with the artery.

A final objection to attempting arterial repair lies in the technical difficulties. Matas,[10] in commenting on the case which he reported in which longitudinal suture of both femoral artery and vein were successfully employed, terms the procedure the "ideal method which is usually practicable only in very recent injuries in which adhesions are not so dense as to preclude mobilization of the vessels." In discussing the transvenous repair, Holman[11] remarks that it depends upon the "ability to control completely all bleeding, either by a tourniquet proximal to the lesion, or by numerous well-placed bulldog arterial clamps."

Despite these objections to arterial repair an attempt was made to restore the continuity of the artery in 23 cases of aneurysms and arteriovenous fistulae on the Vascular Surgical Section at DeWitt General Hospital between June and November 1945. During this period 67 patients with arterial injuries were subjected to operations. Repair was thus attempted in just over one-third of the patients. Success of the repair was demonstrable either by arteriography or by the presence of normal arterial pulsations distal to the lesion in 18 of the 23 cases. The only complications which could be ascribed to the attempted repair were the possible recurrence of an arterial aneurysm in one patient and the recurrence of an arteriovenous fistula in another case after transvenous suture. Subsequent excision of the fistula in the second case was followed by recovery. Table I summarizes the data on the various technics of arterial repair which were employed.

TABLE I

| | Number of Cases | Successful Repair | Failure | Recurrence |
|---|---|---|---|---|
| Longitudinal suture | 2 | 2 | 0 | 0 |
| Transvenous suture | 2 | 0 | 1 | 1 |
| End-to-end anastomosis | 2 | 1 | 1 | 0 |
| Transverse suture | 17 | 15 | 1 | 1 |
| Total | 23 | 18 | 3 | 2 |

A summary of the various locations in which arterial repair was successful is given in Table II.

TABLE II

| | | | |
|---|---|---|---|
| Common carotid | 3 | Superficial femoral | 4 |
| Subclavian | 1 | Popliteal | 7 |
| Brachial | 1 | Posterior tibial | 1 |
| Abdominal aorta | 1 | | |

Longitudinal suture of the defect in the wall of the vein was performed on 18 occasions. In six of these patients the patency of the vein was subse-

quently demonstrated by venography. Obstruction was shown roentgenographically in six others and the result was not determined in the remaining patients.

### LONGITUDINAL SUTURE

Longitudinal suture was first used in the repair of a femoral artery by Postempski[12] in 1886. This method of suture, which was advocated by Matas[13] in his reparative aneurysmorrhaphy, has been generally used in arterial repair. The arteries of two patients in this series were repaired by this technic.

### CLINICAL EXPERIENCES

Case 1.—This 23-year-old male was wounded by shell fragments on November 21, 1944. Approximately two weeks later a pulsating mass was discovered on the anterior aspect of the right thigh. This mass increased in size for a period of time, but then remained stationary.



FIG. 1



FIG. 2

FIG. 1.—Preoperative arteriogram. Case 1. Large aneurysm with arteriovenous fistula of superficial femoral vessels.
FIG. 2.—Preoperative phlebogram. Case 1.

At the time of admission, physical examination disclosed the presence of a large tumor on the anteromedial aspect of the right thigh. A loud, continuous bruit could be heard over it. An arteriogram (Fig. 1), taken on February 9, 1945, showed a large arteriovenous aneurysm, which measured 13 x 8.5 cm. in diameter, involving the superficial femoral artery and vein. A phlebogram (Fig. 2), taken on March 2, 1945, demonstrated displacement of the saphenous vein to the medial side of the thigh. After allowing sufficient time for the development of collaterial circulation, he was operated upon June 28, 1945.

*Operation:* Under continuous spinal anesthesia, an incision was made over Hunter's canal above the aneurysm, and the dilated superficial femoral artery was encircled with rubber tubing. The incision was then carried down the thigh, over the aneurysmal sac, and the sartorius muscle was reflected medially to expose the superficial femoral artery and vein below the sac. The artery in this position was again encircled by rubber tubing. No

attempt was made to control the blood flow through the femoral vein. The artery was then dissected free from the aneurysmal sac and venous bleeding from the opening into the sac was controlled by digital pressure. The defect in the arterial wall measured approximately 1.5 cm. in length. It was closed with a continuous stitch using No. 000 silk on an atraumatic needle. During this procedure, the lumen of the vessel was irrigated with normal salt solution. After completion of the suture, the lower and then the upper rubber tubes were released. Good expansile pulsation across the suture line was observed. The sac was then widely opened and bleeding from the two orifices of the femoral vein was controlled by digital pressure until the ends could be dissected free from the sac and individually ligated. No effort was made to remove the sac. A rubber tissue drain was brought out from the lower end of the wound and the wound was then closed in layers. Following operation, the circulation to the foot and leg appeared to be excellent. An arteriogram (Fig. 3), taken on July 27, 1945, demonstrated the patency of the superficial femoral artery, although the lumen was considerably diminished at the point where the defect had been repaired.

Although pulsations of the peripheral arteries were normal, oscillometry four months later showed that there was still some impairment of circulation. Seven months after operation, the patient still complained of aching in the leg after walking six blocks.

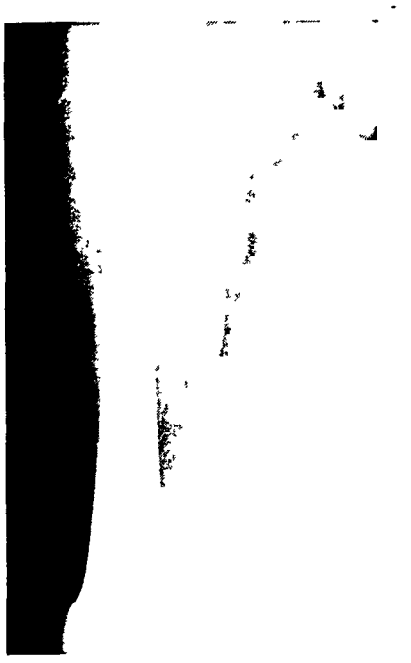


FIG. 3.—Arteriogram. Case 1. After longitudinal repair of femoral artery.

Case 2.—This 23-year-old male was wounded in the right side of the neck, February 13, 1945, by a shell fragment. Immediately after injury, he noted hoarseness of his voice. Débridement was performed, followed by secondary closure of the wound. A few hours after his injury, he noted a thrill in the region of the wound. This condition, in addition to a slight ptosis of the right eyelid, persisted up to the time of admission. Physical examination at that time showed the classical findings of an arteriovenous aneurysm involving the right side of the neck just about the clavicle. In addition, laryngoscopy showed paralysis of the right vocal cord. Pressure upon the aneurysm caused a paroxysm of coughing. The bruit of the aneurysm could be made to disappear upon pressure over the common carotid artery behind the clavicle. This procedure did not produce any symptoms of cerebral ischemia.

*Operation.*—August 2, 1945: Under intratrachial nitrous oxide-ether-oxygen anesthesia, a transverse incision was made above the right clavicle. The muscles were divided close to their insertion and the greatly dilated internal jugular vein was exposed. The inferior thyroid vein was divided and the common carotid artery dissected free. This artery appeared to be about normal in size. It was surrounded by a piece of rubber tubing. Compression of the common carotid artery did not entirely obliterate the bruit heard over the fistula. Dissection was, therefore, carried above the fistula and the common carotid artery was isolated and surrounded by a second piece of rubber tubing. Compression of the artery both above and below the fistula reduced the bruit, but did not completely abolish it. Digital palpation revealed the presence of another large artery lying beneath the fascia lateral to the jugular vein. This artery, which proved to be the inferior thyroid, was divided above and below the fistula. Following this procedure, no further bruit was audible when the contributory vessels were compressed. The jugular vein, accordingly, was ligated above and below the fistula and the carotid artery was dissected away from the aneurysm. The defect in the wall of the carotid was closed with a longitudinal running stitch and the segments of the jugular vein, with the aneurysm which lay posterior to it, was excised. Good pulsation was present in the distal part of the carotid artery one hour after suture. The wound was closed in layers without drainage. Convalescence was uneventful and the patient was discharged four weeks

after operation. At this time, pulsation of the right temporal artery was normal. This pulsation was not affected by compression of the left carotid artery, but it was obliterated when compression was made on the right side of the neck. Six months later, he reported that his only residual symptoms were hoarseness and some drooping of the right eyelid. There was no evidence of recurrence of the aneurysm and he was able to exercise as much as he desired.

COMMENT.—Longitudinal closure of the defect in the arterial wall was successfully accomplished in two cases. Where the opening is small, distortion of the arterial wall by suture is not marked. However, in larger defects, the resultant distortion of the normal contour may curtail the volume flow of blood through the restored artery. Reënforcement of the suture line by the use of a part of the sac wall, may reduce still further the caliber of the vessel. Waugh[14] has reported a case in which the diameter of the vessel was reduced by one-half by this procedure. The maintenance of a full volume flow of blood past the suture line seems to be of importance in preventing subsequent thrombosis at this site.

## TRANSVENOUS SUTURE

Transvenous suture of the fistulous opening between the artery and vein was first suggested by Bickham.[4] This operation has been referred to as the "Matas-Bickham" procedure. The suture is introduced through the scar tissue between the vessels into the lumen of the vein and the opening is closed with a running stitch. The suture is then tied after being passed out through the vein wall so that no suture material is left free in the lumen of the vein. The incision in the wall of the vein is then closed by a running stitch. This technic was used in two cases in the present series.

## CLINICAL EXPERIENCES

Case 3.—This 28-year-old male was wounded in the left knee by a rifle bullet on March 13, 1945. There was considerable hemorrhage which recurred on several occasions. He was admitted to this Vascular Center on April 6, 1945. At that time, there was considerable swelling of the left calf and ankle and a pulsating mass in the popliteal space over which was observed the characteristic thrill and bruit of an arteriovenous fistula. The ankle pulses were absent on the left side and the oscillations were markedly decreased. Arteriogram (Fig. 4), April 17, 1945, revealed an arteriovenous fistula at the level of the head of the fibula. Dye was present in the veins on both sides of the artery. The significance of this observation was not realized until later. Lumbar sympathectomy was performed, August 13, 1945, with improvement in the collateral time and circulation to the left foot.

*Operation*—September 13, 1945: Under continuous spinal anesthesia, the vessels were exposed between the heads of the gastrocnemius muscle in the lower portion of the popliteal space. The popliteal artery lay between two veins in this location. The veins were not separated from the artery, but the entire vascular bundle was surrounded by a piece of rubber tubing both above and below the fistula. Each vein, in turn, was opened and the communication with the artery was visualized. On each side the opening measured approximately 7 mm. in length. It was closed longitudinally according to the Matas-Bickham technic, using a running stitch of No. 000 silk on an atraumatic needle. The sutures were tied outside of the vein. Release of the upper tube now demonstrated a small amount of bleeding of the artery into one of the veins and two additional stitches were taken in the suture line within this vein. At the conclusion of this procedure, there was no further bleeding from

the artery into the vein. The incision on the posterior surface of the vein was then closed with a running longitudinal stitch and all the blood vessels were released. Auscultation now revealed a very faint bruit in the region of the fistula. However, further dissection failed to disclose the source of this faint continuous bruit. Accordingly, it was assumed to be due to the turbulence of the blood stream as it passed over the suture lines. The wound was closed without drainage. After operation, the posterior tibial pulse was excellent and oscillometry showed a considerable improvement in the circulation to the left leg and foot. However, auscultation revealed the persistence of a faint continuous bruit with systolic accentuation. The patient was then sent on a convalescent furlough. Upon his return, he stated that while walking he had suddenly felt something snap in the region of the old aneurysm and upon palpation had noticed a recurrence of the thrill. When he was reëxamined, a loud continuous bruit was audible.



FIG. 4



FIG. 5

FIG. 4.—Preoperative arteriogram. Case 3. Reflux of dye into both popliteal veins.

FIG. 5.—Excised fistula. Case 3. Lower wire indicates third communication overlooked at previous operation. Upper wire placed through recurrent fistula.

*Second Operation.*—November 17, 1945: A longitudinal incision was made posterior to the head of the fibula extending upward medial to the biceps tendon. The peroneal nerve was exposed and retracted laterally and the lateral head of the gastrocnemius muscle was retracted posteriorly to expose the popliteal vessels as they passed through the ring of the soleus muscle. An aneurysm, which measured 2 cm. in diameter, was present at this point. The artery above the aneurysm was freed up and encircled by a piece of rubber tubing. Compression of this tubing now obliterated all bruit in the aneurysm. The head of the soleus muscle was then divided close to its attachment to the head of the fibula and retracted posteriorly, together with its nerve and blood supply. The popliteal artery was thus exposed below the aneurysm. At this point there was a moderately dilated vein overlying the artery. It was possible to observe the turbulent flow of mixed arterial and venous blood in this vein. This vein was divided and ligated in order to expose the popliteal artery below the fistula. The artery was again encircled by a piece of rubber tubing. The proximal and distal arteries were divided and ligated and the component veins were treated in a similar manner and

the aneurysm was excised. Upon examination of the specimen, there were two openings from the artery—one, a small one, shown by the lower pointer (Fig. 5) where a communication with a small vein had apparently been overlooked at the original operation. The larger opening was due to a rupture of the artery into the vein at the point where it had been sutured at the original operation. The patient recovered from this operation without complications but the circulation to the left foot was definitely decreased. Oscillations at the ankle were less than one-quarter of those on the normal side. In spite of this fact, the circulation was fairly well maintained so that the patient was able to walk for as much as three blocks before developing signs of intermittent claudication.

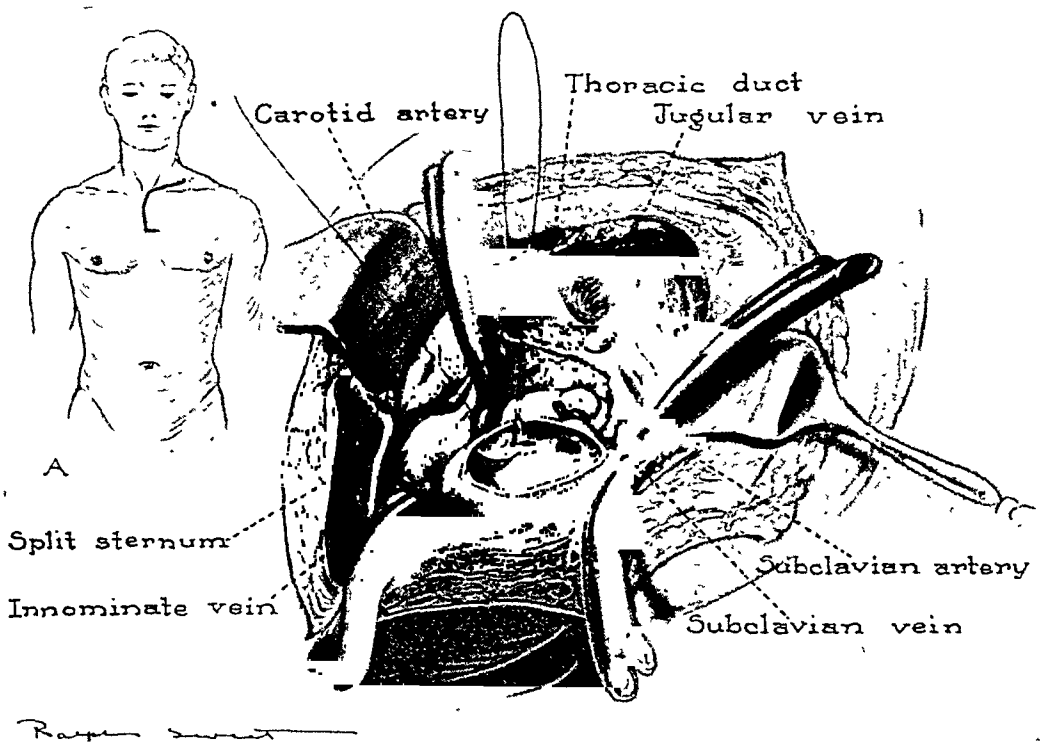



FIG. 6.—Transvenous repair of fistula involving left subclavian artery and innominate vein. Case 4.

Case 4.—This 24-year-old male was struck by shell fragment just above the left clavicle on July 29, 1944. After the initial débridement, it was noted that his left radial pulse was absent although, subsequently, it returned. From the time of the injury, the patient believed that the temperature of the left upper extremity was lower than that on the right side. Except for difficulty in articulation for the first few days after injury, he had no complaints. However, a loud continuous bruit was audible over the left sternoclavicular joint. He was admitted to the Vascular Center in October, 1944. Venous pressure was found to be 16.4 cm. of water on the left side and 13.4 cm. on the right. The circulation time was 20 seconds on the left and 9 seconds on the right. Attempts to compress the aneurysm by pressure in the supraclavicular region were unsuccessful. In spite of the fact that the aneurysm was close to the heart, no evidence of cardiac enlargement was noted during a long period of observation.

*Operation.*—September 10, 1945: Under endotracheal, nitrous oxide-ether-oxygen anesthesia, a transverse supraclavicular incision was made on the left side, extending down over the manubrium to the second rib, thence lateralward to the costochondral junction. (Fig. 6.) The muscles attached to the clavicle and sternum were divided close to their

insertions. The internal jugular vein was thus exposed and the turbulent mixing of arterial and venous blood could be observed. Pressure on the junction of the internal jugular and subclavian veins stopped the bruit in the fistula. The common carotid artery on the left side was then exposed. Its pulsation was feeble and the wall was thick. Occlusion of this artery, however, did not prevent the thrill in the aneurysm. Further dissection revealed a greatly dilated innominate vein. It was impossible to expose this vein adequately without opening the thorax. Accordingly, the medial 2.5 inches of the left clavicle were resected subperiostially, leaving the sternoclavicular articulation intact. The tissues were then freed beneath the sternum in the midline and the manubrium was split to the upper border of the second rib, and then cut transversely at this level. The left half of the manubrium was then readily retracted lateralward to expose the thymus lying on the large dilated innominate vein. Some branches of this vein were ligated and divided. The innominate vein and left carotid artery were retracted medially to expose the left subclavian artery as it arose from the arch of the aorta. The subclavian artery was considerably larger than the carotid and the walls were thin. The pressure within the artery seemed to be low. It was encircled by a fine catheter which was fitted to a Bethune tourniquet. Compression of the subclavian artery at the arch of the aorta obliterated the thrill in the aneurysm. Although the bruit ceased abruptly as soon as the subclavian artery was compressed, within a short interval a faint bruit was again audible, probably indicative of collateral circulation. The internal jugular vein was then divided above its junction with the subclavian. Dissection on the medial side of the internal jugular vein revealed a large lymphatic duct which entered the junction of the jugular with the subclavian. The phrenic nerve was retracted medially and the scalenus anticus muscle was divided in order to expose the second portion of the subclavian artery. The internal mammary artery was carefully preserved but the costocervical and the thyrocervical trunks were ligated. The subclavian artery distal to the fistula was markedly reduced in caliber. It was surrounded in this location by a piece of rubber tubing. The first portion of the subclavian artery just proximal to the origin of the vertebral artery was then exposed and surrounded by a second piece of rubber tubing. With the subclavian artery compressed just proximal to the vertebral artery and distal to the fistula and with the vertebral artery compressed, the bruit was abolished. The innominate vein no longer filled with arterial blood. The subclavian and innominate veins were then occluded by additional pieces of rubber tubing and the innominate vein was opened on its anterior aspect close to the junction of the jugular with the subclavian vein. The vein was flushed out with normal saline. It was possible to see an aperture which measured approximately 1 cm. in length lying over the subclavian artery. (Fig. 6.) The opening from the artery into the vein was sutured from within the vein by the Matas-Bickham technic, using No. 000 silk. The suture was started from outside the vessel, passing into the lumen and then after closing the opening with a running stitch the suture was doubled back on itself and the ends brought outside of the vein to be tied at the starting point. After this suture had been completed, the distal artery, the vertebral, and then the proximal artery, in turn, were released. There was some slight bleeding into the vein which was controlled by an additional stitch. The incision on the anteromedial surface of the innominate vein was then closed with a running longitudinal stitch. The two halves of the manubrium were approximated with two steel wire sutures and the muscles and superficial tissues closed in layers.

The patient developed a wound infection which necessitated incision and drainage two weeks after the original operation, but satisfactory recovery then took place. Although there were no signs of circulatory insufficiency of the left upper extremity, the radial pulse continued to be markedly diminished and the oscillations were reduced. Six weeks after operation, a phlebogram demonstrated the patency of the left innominate vein. Five months after operation the patient reported that he had noticed no recurrence of the fistula. However, he was short of breath and experienced precordial pain on exercise. Since there was no cardiac enlargement even before operation it is unlikely that the fistula could have caused serious cardiac disturbance.

COMMENT.—Transvenous suture, although it has been considered a logical procedure, has two decided drawbacks. Since the artery need not be fully mobilized, a second and even a third communication may be overlooked. This complication has been reported by Reid and McGuire[8] and accounted for the persistence of the arteriovenous fistula in Case 3 of this series. The second objection is the fact that the arterial wall may be weakened or defective either close to the fistula or at some other point. Without careful scrutiny of the arterial wall both from within and from without, this damaged area may be overlooked. Subsequent rupture with the formation of an aneurysm may result.



FIG. 7.—Preoperative arteriogram. Case 5. Superficial femoral arteriovenous aneurysm.

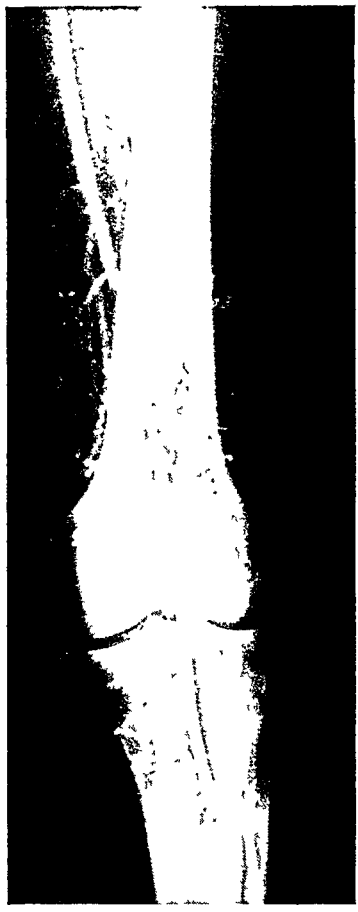


FIG. 8.—Postoperative arteriogram. Case 5. Failure of end-to-end anastomosis. Excellent collateral circulation.

## END-TO-END ANASTOMOSIS

The first successful end-to-end anastomosis of an artery was reported by Murphy[15] in 1896. Since that time numerous reports of this procedure have been made, especially following the work of Carrell.[16] Few demonstrably successful cases have been reported. This technic has been employed in two cases in the present series.

CLINICAL EXPERIENCES

Case 5.—This 25-year-old male was wounded in the left thigh on January 15, 1945. He developed signs of an arteriovenous fistula in the lower part of the thigh. At the time of admission to the Vascular Center, July 15, 1945, he showed characteristic signs of an arteriovenous fistula involving the lower portion of the femoral vessels. Arteriogram (Fig. 7), July 20, 1945, showed an aneurysmal sac lying to the medial side of the femoral artery, with a communication into the lower femoral and popliteal veins. Sympathectomy was performed on July 30, 1945. After this operation, the collateral circulation seemed to be adequate.

*Operation.*—August 23, 1945: A longitudinal incision was made over the lower part of the adductor canal. The femoral artery was exposed above and below the fistula. The aneurysm was present on the lateral side of the artery. With digital compression of the veins, the artery was dissected free from the aneurysm and from the vein. The opening into the vein was closed with a longitudinal running stitch. Two large defects were present in the arterial wall. Because so little sound arterial wall remained, a resection of the damaged portion was performed with end-to-end anastomosis. After release of the rubber tubing, expansile pulsation was transmitted across the suture line. The wound was closed without drainage. After operation, the peripheral pulses were good and oscillations at the left ankle were three units in comparison to a reading of five units on the normal side. With the excellent peripheral pulses and practically normal circulation, it was believed that a successful repair had been accomplished. However, an arteriogram, taken six weeks after the operation (Fig. 8), showed that the segment had been completely obliterated and that the circulation was carried on entirely by means of collateral vessels.

Case 6.—This 28-year-old male was wounded by a rifle bullet in the left thigh on February 28, 1945. The wound of entrance was two inches below Poupart's ligament. After débridement in the forward area, an arteriovenous fistula was discovered in this region. He was admitted to the Vascular Center on July 1, 1945. Arteriogram, September 7, 1945, showed a communication between the femoral vessels just distal to the profunda.

*Operation.*—October 1, 1945: A semilunar incision was made over the upper portion of the thigh with its center at the wound of entrance. The common femoral artery was exposed below Poupart's ligament. It was greatly dilated with thin walls. This artery was surrounded by a piece of rubber tubing. Compression of this tubing now obliterated the thrill in the arteriovenous fistula although a slight bruit was still audible. The artery was again exposed below the profunda femoris, but further auscultation revealed that the aneurysm involved the superficial femoral artery below this second temporary ligature. Accordingly, the dissection was carried further down the thigh by retracting the sartorius muscle medially and the femoral artery was exposed in Hunter's canal. With both the proximal and the distal artery occluded, the bruit was completely abolished. The artery was separated from the vein by sharp dissection. Some brisk venous bleeding was controlled by digital pressure until the femoral vein could be sutured. It was found that the wall of the femoral artery had been destroyed over a very wide range and there were two perforations in it, one on the lateral and one on the medial side. Accordingly, the artery was divided and the damaged portion excised. The artery had to be dissected free for a distance of two inches below and upward to the point at which the profunda femoris vessel left it, in order to obtain sufficient relaxation to permit suture. An end-to-end anastomosis was then performed, using a continuous running stitch of No. 000 silk. After release of the rubber tubing there was some bleeding which was controlled with additional stitches. At the conclusion of the operation, there was good pulsation transmitted across the suture line. The wound was closed without drainage.

Convalescence was uneventful and the peripheral pulses remained excellent. Oscillometry showed no diminution on the side of operation. Arteriogram and phlebogram, two months after operation, demonstrated patency of the vessels. The patient reported five months after operation that he had been working steadily but that he had pain in the lower part of

the leg when standing for a long time or walking very far. There was no swelling and the circulation was good.

COMMENT.—End-to-end anastomosis was successful in one of the two cases in this series in which it was attempted. Obliteration occurred in the first case. The patient recovered, however, since the collateral circulation was abundant, and little vascular insufficiency resulted.

### TRANSVERSE SUTURE

Transverse suture of the laceration in the arterial wall has been recommended by Learmouth[17] if the wound does not involve more than one-third of the circumference. It has been our experience that transverse suture is

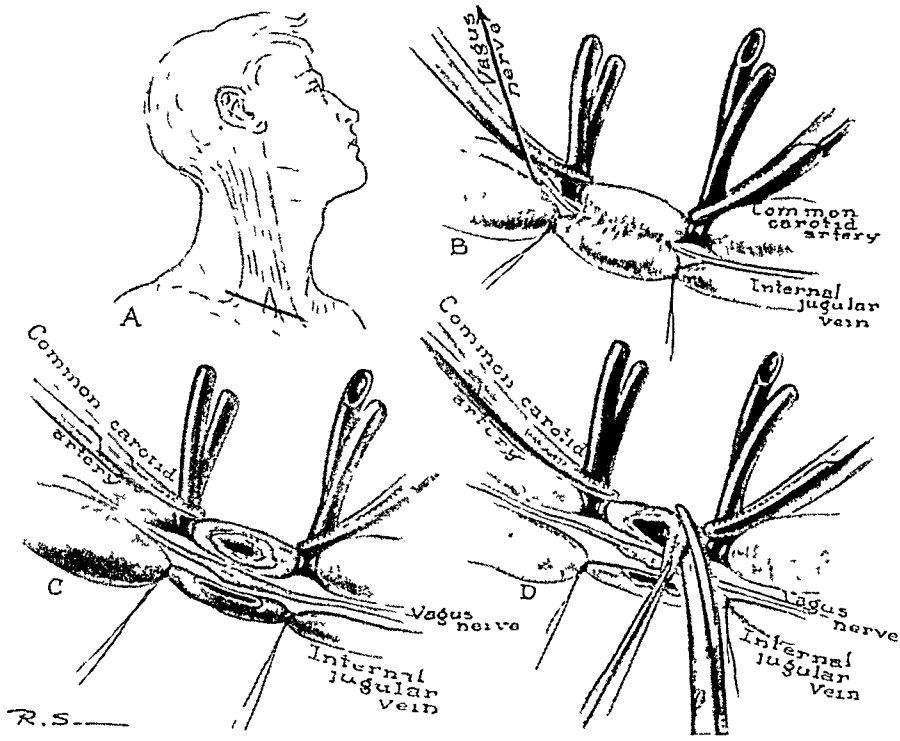



FIG. 9.—Carotid-jugular arteriovenous aneurysm. (A) Position of incision. (B) Circulation through component vessels controlled. (C) Fistula divided. (D) Excision of damaged portion of arterial wall.

possible even though more than three-fifths of the vessel wall is lacking. Control of the circulation through the artery above and below the fistula is first obtained by the use of sections of rubber tubing. As shown in Figure 9-B the rubber tubing is clamped close to the vessel wall by means of fine curved hemostats. The use of rubber tubing prevents damage to the arterial wall and the hemostats facilitate manipulation of the artery during the dissection and subsequent repair. After control of the major arterial supply has been obtained, auscultation at the site of the fistula by means of a sterile stethescope is essential in order to exclude additional arterial components. Persistence of bruit indicates that some other artery is still connected with the fistula. When the completeness of the arterial control has been verified the vein is

encircled above and below the fistula with heavy silk thread. With the component vessels controlled the artery is then dissected free. After irrigation of the lumen with normal saline the entire arterial wall is inspected both from within and from without. The damaged arterial wall is then excised (Fig. 9-D) in an elliptical fashion. Relaxation can be obtained by approximating the vessel on either side of the defect with the aid of the rubber tubing used to control the circulation. Especially in the presence of an arteriovenous fistula,

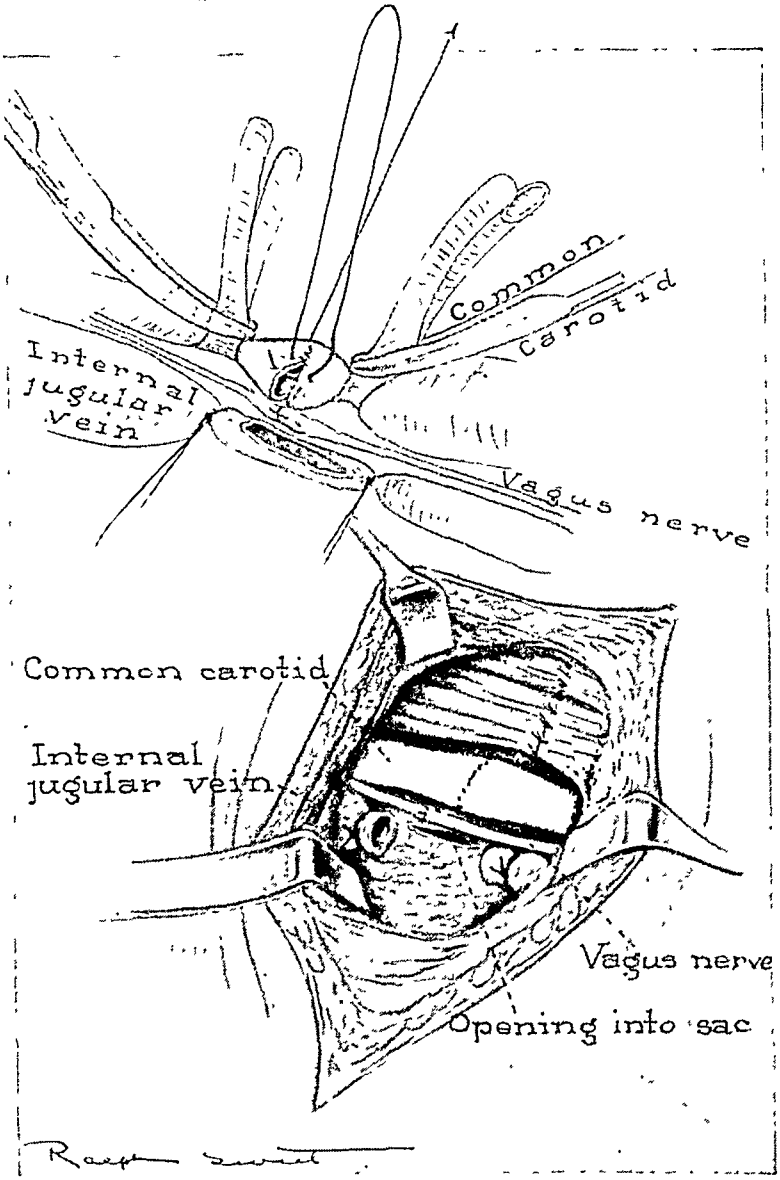



FIG. 10.—Transverse repair of defect in carotid artery. Insertion of running stitch through entire thickness of arterial wall. Repair completed.

sufficient dilatation with elongation of the afferent artery has taken place to permit this approximation. Additional relaxation can be obtained by dissection of the artery up to the point of origin of the nearest branch. However, no important collateral vessel should be sacrificed. After approximation of the edges of the arterial wall the defect is closed by a running stitch which passes through all layers (Fig. 10). It may be doubled back on itself and tied at its point of origin. We have used No. 000 silk (Deknatel) on an atraumatic

needle and have passed this suture material through sterile mineral oil. After completion of the closure, first the distal and then the proximal portion of the artery is released. Bleeding from the suture line is generally mild and stops spontaneously. Otherwise an additional stitch of No. 00000 silk may be needed. Frequently there is some distortion of the artery due to a bulge of the redundant part of the normal vessel wall opposite the line of suture. This distortion has not apparently interfered with the volume flow of blood which passes the suture line. In no case, when good expansile pulsation was observed distal to the suture line after transverse closure, did subsequent thrombosis occur.

Frequently extensive dissection would have been required in order to isolate all the venous components of an arteriovenous fistula. Under such circumstances, after complete control of the arteries had been obtained, reflux bleeding was simply controlled by digital pressure as the artery was dissected from the vein. The opening into the vein was then closed with a suture.

Transverse suture was successful in 15 of the 16 cases in which it was attempted.

## CLINICAL EXPERIENCES

Case 7.—The patient, a 24-year-old male, was wounded in the neck, arms and legs by multiple mortar fragments on April 1, 1945. He developed subcutaneous emphysema of the neck which subsided spontaneously, but subsequently characteristic signs of arteriovenous fistula on the left side of the neck at the level of the thyroid cartilage were observed. These signs persisted up to the time of admission to the hospital on May 27, 1945. In addition, laryngoscopic examination showed paralysis of the left vocal cord. Three months after he was wounded, compression of the common carotid artery below the fistula produced no evidence of cerebral ischemia.

*Operation.*—July 23, 1945. Under local anesthesia, an oblique incision was made parallel to the skin creases at the level of the thyroid cartilage. Dissection was carried down medial to the sternomastoid muscle and the common carotid artery was isolated below the fistula. A rubber tube was placed about the artery at this point. The common carotid artery was again isolated above the fistula and treated in a similar manner. The jugular vein was greatly dilated. It was dissected free and a heavy black silk thread placed about it both above and below the fistula. The vagus nerve was then freed up to the point where it was incorporated in the scar between the carotid artery and the jugular vein. One per cent procaine was injected into the vagus nerve above the line of scar tissue. With the common carotid artery compressed both above and below the fistula, the vagus nerve was dissected free and the communication between the artery and vein was opened. The communication measured 1 cm. in diameter. The defect in the arterial wall was on the posterolateral side and, on inspection, it was noted that the media was defective in the region of the aperture. The defective portion of the wall of the common carotid artery was then excised. After relaxation of tension, the defect in the arterial wall was closed in a transverse direction by a running stitch doubled back on itself. After release of the rubber tubing, pulsation took place across the suture line. There was no evidence of narrowing of the vessel. The opening into the jugular vein was then sutured with a longitudinal running stitch. After excision of the damaged segment of the vagus nerve, the two ends were united. At the conclusion of the operation, the carotid artery was again examined. Good pulsatile flow could be demonstrated above the suture line. The wound was closed in layers without drainage.

Recovery occurred without complications. He was discharged from the hospital one month after operation. It was possible, in the postoperative period, to demonstrate the patency of the left common carotid artery by noting the fact that the temporal pulse on the

left side was unaffected by compression of the right common carotid artery, but could be obliterated by compression of the one on the left side. Six months after operation, he reported that he still was unable to work and that he could not exercise as much as he would like to because of being short-winded. There was no recurrence of the swelling in the neck. Normal voice had not yet returned.

Case 8.—This 21-year-old male sustained many wounds of the chest, abdomen, and right leg from mortar fragments on December 21, 1944. During the course of hospitalization it was discovered that he had an arteriovenous aneurysm of the right popliteal space. At the time of admission to this hospital, March 28, 1945, there was a pulsating mass in the right popliteal space with a characteristic thrill and bruit. Preoperative arteriogram, May 22, 1945, (Fig. 11), showed considerable reflux of dye into the dilated popliteal vein.



FIG. 11.—Preoperative arteriogram. Case 8. Popliteal arteriovenous fistula.



FIG. 12.—Postoperative arteriogram. Case 8. After transverse repair of popliteal artery.

The communication between the artery and the vein seemed to be at the superior level of the patella. On July 9, 1945, a lumbar sympathectomy was performed. This operation was followed by an excellent return of collateral circulation.

*Operation.*—August 9, 1945. Under continuous caudal anesthesia a Z-shaped incision was made with the transverse bar across the popliteal crease. The incision was deepened along the tendon of the semimembranosus muscle. Many small veins were encountered which entered the greatly dilated popliteal vein. The section of rubber tubing was placed about the entire vascular bundle including both the artery and the vein. Dissection was then carried on below the fistula and the popliteal artery was isolated and encircled by a section of rubber tubing. The popliteal vein was surrounded by heavy silk cord. Further dissection above the aneurysm resulted in separation of the artery from the vein so that each was independently controlled. With the component vessels occluded, the artery was

dissected from the vein and the communication was severed. This defect measured 1 cm. in length. The opening in the wall of the vein was closed with a running longitudinal stitch. The arterial wall was found to have been damaged to an extent of about one-half its circumference. Accordingly, a wedge-shaped portion of the lateral wall was excised and the defect closed in a transverse direction with a continuous suture of No. 000 silk placed through all coats of the vessel. Some bleeding which followed release of the occlusive rubber tubing was controlled with a suture. There was only slight reduction in the diameter of the artery at the point of suture and, after release of the rubber tubes, vigorous pulsation was noted below the suture line. At the conclusion of the operation, the posterior tibial pulse was full and bounding. The wound was closed without drainage. Postoperatively, normal pulses were present at the right ankle, and oscillometry on the right side was almost equal to that on the left. Arteriogram, taken on August 24, 1945, (Fig. 12), showed practically no distortion at the suture line. Reëxamination four months after operation disclosed a normal peripheral circulation and he reported six months after operation that he was able to walk several miles without any trouble.

Case 9.—This 22-year-old male was struck by a shell fragment, July 18, 1944, just above the right clavicle. In addition, he sustained severe wounds of both legs and the left forearm. Amputation of the left forearm was performed. After treatment in other General Hospitals, he was admitted to this hospital, March 5, 1945, with classical signs of an arteriovenous aneurysm at the base of the neck on the right side. It was difficult to obliterate the bruit by pressure above the clavicle. Despite the length of time between wounding and operation, he developed no signs of cardiac damage.

*Operation.*—August 20, 1945: Under endotracheal nitrous oxide-ether-oxygen anesthesia, a supraclavicular incision was made. The muscles attached to the sternum and clavicle were divided at their insertion in order to expose the internal jugular vein. Both the right and left inferior thyroid veins were divided and ligated and the deep cervical fascia was incised. The internal jugular vein was retracted laterally and dissection was carried down behind the clavicle to expose the innominate artery. This artery was surrounded by a piece of rubber tubing, fitted to a Bethune tourniquet. Occlusion of the artery caused marked decrease in the bruit over the fistula. Compression of the common carotid artery did not affect the bruit. The rubber tubing was then transferred to the subclavian artery just proximal to the origin of the vertebral. The scalenus anticus muscle was then divided, after retracting the phrenic nerve medialward, to expose the second portion of the subclavian artery. The communication appeared to involve the internal jugular vein and the subclavian artery just proximal to the origin of the thyroid axis. The jugular vein was divided and its upper portion ligated. After compression of the subclavian artery proximal and distal to the fistula, the vein was dissected free from the artery to expose a small opening approximately 0.5 cm. in diameter. This opening was closed transversely with interrupted stitches of No. 000 silk (Fig. 13). Following release of the occluding rubber tubing good pulsation was present in the artery distal to the suture line. The jugular vein was ligated close to its junction with the right subclavian and the wound was closed in layers without drainage. Convalescence was uneventful, and at the time of discharge the right radial pulse was normal.

Case 10.—This 30-year-old male sustained multiple wounds from shell fragments on February 7, 1945. While he was a patient at another hospital, he became aware of a thrill in the left popliteal space. He was admitted to the Vascular Center on May 10, 1945. At that time, examination disclosed characteristic evidence of an arteriovenous fistula involving the vessels in the left popliteal space. Arteriogram, May 25, 1945, (Fig. 14), showed considerable reflux of dye into the popliteal vein. Left lumbar sympathectomy was performed on July 30, 1945. The collateral circulation was excellent following this operation.

*Operation.*—August 26, 1945: Under continuous caudal anesthesia, a curved incision was made across the left popliteal space. The popliteal artery above and below the fistula was exposed and surrounded by pieces of rubber tubing, and the popliteal vein was surrounded by pieces of heavy black silk. The artery was then dissected away from the vein.

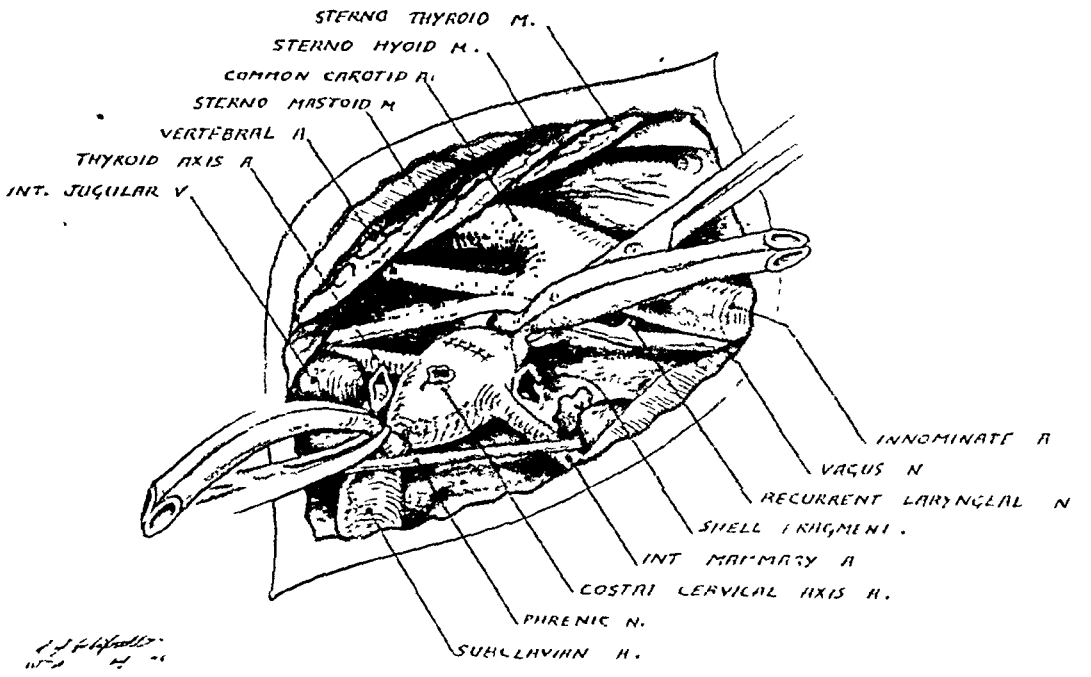



FIG. 13.—Transverse repair of right subclavian-jugular arteriovenous fistula. Case 9.

leaving a portion of the venous wall attached to the artery. After dissecting the artery away from the fistula, it was discovered that the artery communicated with two veins. The openings in both veins were closed with running sutures. The artery was then carefully irrigated with saline and rotated inward to expose the two openings. Since there was apparently normal arterial wall between the two defects, each opening was closed separately by a continuous stitch of No. 00000 silk, which was doubled back on itself. After release of the distal and proximal compression of the popliteal artery, some further bleeding took place which was controlled by an additional stitch. Normal pulsation of the popliteal artery was present below the lines of suture at the time of closure. Subsequent to operation, no disturbances of the peripheral circulation were noted. The oscillometry at the ankle was equal to that before operation. Arteriography, September 11, 1945, (Fig. 15), showed some dilitation of the artery at the line of suture. This examination was repeated on November 23 and, at that time, the distortion of the lumen of the artery was not as pronounced. Phlebogram demonstrated patency of the popliteal vein. Five months after operation, he reported that there had been no recurrence of the arteriovenous fistula, and no swelling in the region of the aneurysm. He still was unable



FIG. 14 FIG. 15

FIG. 14.—Preoperative arteriogram. Case 10. Popliteal arteriovenous fistula.

FIG. 15.—Postoperative arteriogram. Case 10. Slight dilation of popliteal artery following transverse repair.

to exercise as much as he was inclined to because of weakness and aching in both legs, associated with some muscle cramps on the left side.

Case 11.—This 21-year-old male was wounded August 28, 1944, in the right leg by numerous shell fragments. Signs of an arteriovenous fistula were noted soon afterwards in the right popliteal space. He was originally treated in another hospital for his other wounds and was then admitted to this Vascular Center on January 16, 1945. Collateral circulation was very slow to develop, and he showed considerable evidence of impairment of circulation. Right lumbar sympathectomy was performed on August 2, 1945. After this operation, the circulation was considered adequate for operation on his arteriovenous aneurysm.

*Operation.*—August 27, 1945. Under continuous spinal anesthesia an incision was made over the popliteal space and the popliteal artery was dissected free above the fistula. Some difficulty was experienced in isolating the popliteal artery below the fistula, due to the presence of numerous large veins draining the medial head of the gastrocnemius muscle. After isolation of the artery below the fistula, a pneumatic tourniquet, which had previously been applied about the thigh, was inflated to 200 mm. of mercury and the popliteal artery was separated from the vein. The communication measured approximately 7 mm. in diameter. A portion of the venous wall was left attached to the artery. The defect in the arterial wall was sutured in a transverse direction with a continuous silk stitch. The venous side of the communication was simply ligated. At the conclusion of this procedure there was good circulation across the suture line. However, on auscultation, it was possible to localize a bruit to a point approximately 2.5 inches below the first arteriovenous fistula. Dissection was then carried down along the posterior tibial artery, carefully preserving the branches, in order to disclose this second arteriovenous fistula. The arteries proximal and distal to the fistula were again occluded with rubber tubing, while the bleeding from the venous side was controlled by digital pressure as the artery was cut away from the fistula. A large opening, measuring approximately 1 cm. in length, was disclosed. The vein was sutured with a running stitch of silk and, although there was a fairly large gap between the two ends of the artery with destruction of more than three-fifths of its wall, a transverse closure was effected. At the conclusion of the operation, good pulsation was present below the suture line. The wound was closed in layers without drainage. In the postoperative period, whereas oscillations at the ankles had been reduced on the affected side to one-quarter of the normal, after operation, they were 50 per cent greater than those on the normal side. Arteriogram, taken three months after operation, showed that there was little distortion of the vessel at either of the sutured areas. Five months after operation he reported that he had had no return of his aneurysm and his only complaint was that the lower part of his leg became weak in case he walked too fast.

Case 12.—This 24-year-old male was wounded on March 22, 1945, by a 25 caliber bullet which passed through the popliteal space of the right side. There was no nerve damage and very little hemorrhage, but approximately two weeks after injury the patient noted the characteristic thrill of an arteriovenous aneurysm. He was admitted to this Vascular Center on April 26, 1945. Since the collateral circulation was slow to develop and his feet were cold and moist, a right lumber sympathectomy was performed on August 8, 1945. Following this operation, the collateral circulation appeared to be adequate.

*Operation.*—August 30, 1945: Under continuous spinal anesthesia the popliteal vessels were exposed in the midportion of the popliteal space. The popliteal artery was surrounded by a piece of rubber tubing both above the fistula and below it. The vein was similarly controlled above and below the fistula. A small aneurysmal dilitation of the artery was present on the side opposite the communication with the vein. After excision of this portion of the arterial wall and the damaged portion of the arterial wall surrounding the fistula, the defect was found to involve approximately one-half of the circumference. This defect was closed transversely with a running stitch. Considerable difficulty was encountered from bleeding at the suture line, following release of the rubber tubing, but this was controlled with additional stitches. The vein was closed in a longitudinal fashion. The wound was closed without

drainage. Two weeks after operation, oscillations on the affected side were greater than those on the normal side. Six months later he reported that he had had no recurrence of the fistula. However, he noted pain and fatigue in the calf after walking seven or eight blocks.

Case 13.—This 27-year-old male was wounded by shell fragments in the right thigh, trunk and face on January 20, 1945. During convalescence from these wounds, an arteriovenous fistula of the right femoral vessels was noted. He was admitted to this Vascular Center on May 18, 1945. Arteriogram, taken on May 20, 1945, revealed an arteriovenous fistula in the upper portion of the superficial femoral vessels on the right side and, in addition, a small aneurysm on the lateral side of the artery (Fig. 16). Because of impaired circulation, a lumbar sympathectomy was performed on August 8, 1945. After this operation there was considerable improvement in the collateral circulation.

*Operation.*—September 13, 1945: The superficial femoral artery was exposed in the upper third of the thigh. Rubber tubes were placed about the artery both above and below the fistula. A pneumatic tourniquet was then inflated and the artery was dissected away from the vein and from the aneurysm. The aneurysm was found to be present on the posterolateral side of the artery while the opening between the artery and the vein was on the posteromedial side. The opening into the vein was closed with a longitudinal running stitch and the pneumatic tourniquet deflated. The defect in the arterial wall measured approximately 1.5 cm. in length. The portion of the arterial wall which was damaged, including the segment between the opening into the vein and the opening into the aneurysm, was excised. Approximately three-quarters of the circumference was lacking. In order to approximate the two ends, it was necessary to free-up the artery, both above and below the fistula, for a distance of approximately 1.5 inches. No large branches were found. Because of the location of the arterial defect, the suture line was oblique rather than either transverse or longitudinal. A small amount of bleeding took place from the suture line after release of the rubber tubing, and this required an additional stitch. There was a slight distortion of the arterial wall on the opposite side from the repair. No attempt was made to remove the aneurysm. The wound was closed without drainage. Postoperative convalescence was normal. Oscillometry before operation showed a maximum of two on the right side, and seven on the left. Following repair of the femoral artery, the oscillations were three on the right side, and 3.5 on the left. Arteriography, three months after repair showed normal continuity of the superficial femoral artery (Fig. 17). A phlebogram demonstrated patency of the femoral vein. However, four months after operation he reported that he was not able to exercise as much as he desired because if he walked too much his leg became swollen below the knee. There was no recurrence of the arteriovenous fistula, and no evidence of swelling in the region of the aneurysm.

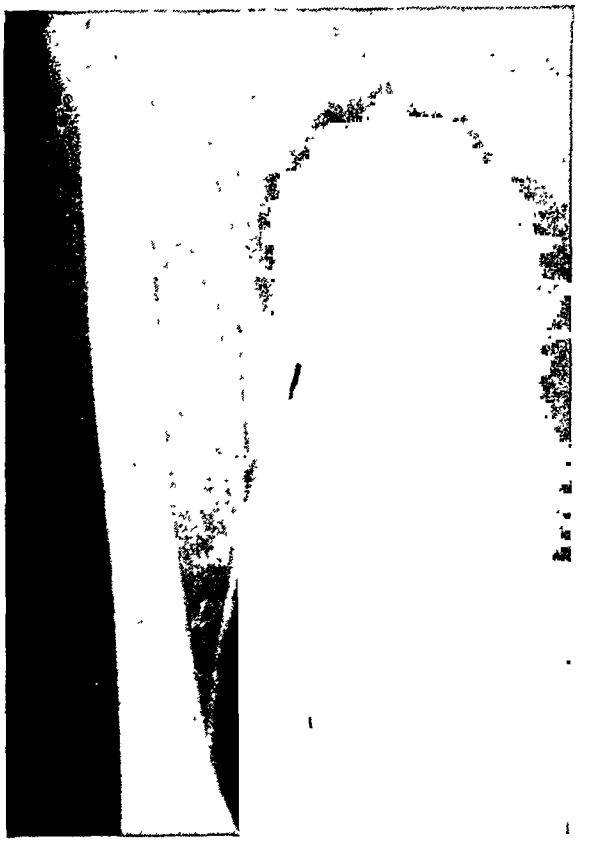


FIG. 16.—Aneurysm with arteriovenous fistula of superficial femoral artery. Case 13. Preoperative arteriogram.

Case 14.—This 19-year-old male was wounded by shell fragment in the neck, on February 18, 1945. The following day, he noted a buzzing sensation in the right side of the neck. At the time of admission to this Vascular Center, March 13, 1945, he had characteristic

signs of an arteriovenous fistula involving the vessels at the base of the neck, on the right side. In addition, there was paralysis of the right vocal cord.

*Operation.*—September 24, 1945. (Cf. Figs. 9 and 10.) Through a transverse supraclavicular incision, after dividing the muscles attached to the sternum and clavicle, the internal jugular vein was exposed. The inferior thyroid vein was divided and ligated, and the jugular vein retracted laterally to expose the carotid artery. A piece of rubber tubing was placed about this artery. Occlusion of this tubing obliterated the thrill but did not prevent the bruit in the arteriovenous fistula. However, when the common carotid above the fistula was also compressed by rubber tubing, all bruit was prevented. The internal jugular vein was then controlled above and below the fistula with silk ligatures and the artery was dissected from the vein. The opening from the artery into the vein measured approximately 1 cm. in length. Posterior to the vein there was a large aneurysmal sac which extended down into the superior mediastinum. A considerable portion of the venous wall was missing and, accordingly, the vein was divided and ligated. The damaged portion of the arterial wall was excised and the defect was closed in the transverse direction. Following completion of this procedure, the tubing was released and good arterial pulsation was felt distal to the suture line. The vagus nerve, which was incorporated as part of the scar tissue about the sac, was sutured after excision of the damaged portion. The wound was closed without drainage. Four months after operation he reported that, although his voice had not improved, there had been no recurrence of the aneurysm or the fistula.

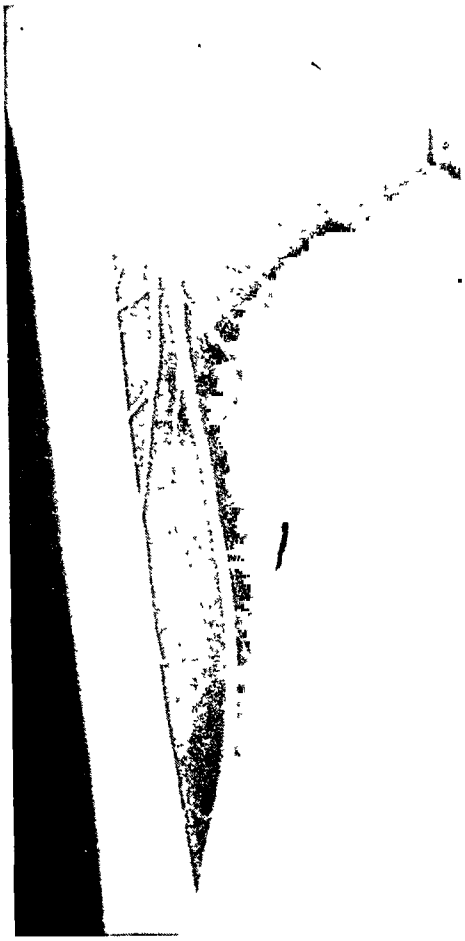


FIG. 17.—Postoperative arteriogram. Case 13. After diagonal suture.

Case 15.—This case, which will be reported in detail elsewhere, is that of a 25-year-old male who sustained a perforating wound of the abdomen on May 14, 1945. A 25-caliber bullet entered the abdomen three inches below the ensiform cartilage, just to the right of the midline and passed out through the back at the level of the second lumbar vertebra. He was immediately paralyzed below the waist. A celiotomy, performed on the day of injury, revealed a large retroperitoneal hematoma. Ten days later, laminectomy was performed for the cord injury. Six weeks after the original injury, the patient complained of epigastric pain and, on examination, evidence of an arteriovenous fistula was observed.

*Operation.*—September 27, 1945. Under endotracheal nitrous oxide-ether-oxygen anesthesia, a left paramedian incision was made. Abdominal exploration revealed a large pulsating mass in the right upper quadrant. In order to expose the aorta, dissection was carried out in the extraperitoneal region, reflecting the contents of the left side of the abdomen to the right. The aorta was encircled by pieces of rubber tubing above and below the fistula which was present just below the right renal artery. The aorta was then dissected free from the aneurysm and the opening into the latter closed, with a running stitch. The opening into the aorta was closed with a transverse running stitch. After operation, although there was a stormy period for 12 days, due to urinary suppression and hypertension, the patient

made an excellent recovery. The peripheral pulses were normal. Figure 18 shows the patient five months after operation.

Case 16.—This 26-year-old male was wounded by shell fragments in the left thigh on March 30, 1945. He developed some numbness and tingling in his left foot and a pulsating mass 8 cm. below the inguinal ligament, directly beneath the scar of the wound. There was a systolic thrill and a high-pitched bruit over this mass but there was no diastolic component to the murmur. Arteriogram, August 10, (Fig. 19), revealed an aneurysm the size of a plum, arising from the upper portion of the superficial femoral artery. Lumbar sympathectomy was performed on October 4, 1945.

*Operation.*—October 18, 1945. The superficial femoral artery was exposed above the aneurysm, medial to the sartorius muscle. It was encircled by a piece of rubber tubing. Compression on this tubing now caused the aneurysmal sac to collapse. The artery below the aneurysm was then exposed, and a tube placed about it to control the retrograde circulation. With both the proximal and distal arteries occluded, the sac was exposed and incised. After removal of the clots and fresh blood, the openings of the afferent and efferent arteries were observed to be separated by approximately 1 cm. The artery was then freed from the sac by sharp dissection. There was considerable scar tissue, as well as some edema present. With the aid of traction applied by means of the rubber tubes, the orifices of the artery could be approximated. Accordingly, after cutting away excess portions of the sac, the opening was closed in a transverse fashion with a continuous running stitch. In addition, numerous interrupted stitches of silk were used in order to approximate the scar tissue wall of the sac so as to take tension off of the suture line. Upon release of the constricting tubing pulsatile flow took place across the suture line. The artery in this location appeared to be quite small and contracted. There was considerable distortion of the femoral artery at the site of suture. The wound was closed without drainage. The postoperative course was uneventful. Oscillations at the left ankle were about two-thirds normal. Arteriogram (Fig. 20), taken six weeks after operation, revealed considerable distortion of the femoral artery. Three months after operation, the patient reported recurrence of the bruit. Since there was considerable degeneration and fibrosis of the arterial wall in the region of the aneurysm, it is quite possible that this scar tissue had given way leading to recurrence.

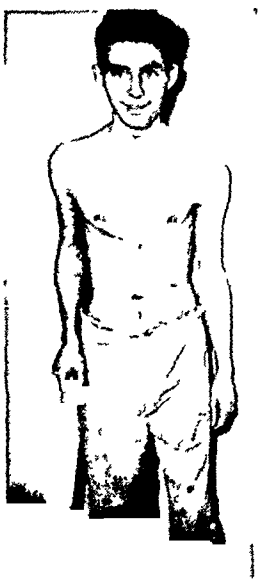


FIG. 18. — Case 15: Five months after repair of abdominal aorta for arteriovenous fistula.

Case 17.—This 29-year-old male was wounded in the left thigh by mortar fragments on November 11, 1944. He sustained a compound fracture of the left femur. Six weeks after injury, an arteriovenous fistula was discovered close to the site of fracture. He was admitted to this Vascular Center on May 8, 1945. Arteriography (Fig. 21), on May 25, 1945, disclosed a simple arteriovenous fistula just below the fracture line. There was considerable distortion of the superficial femoral vein, probably due to the scar tissue about the fracture. Lumbar sympathectomy was performed on September 13, 1945. Collateral circulation was satisfactory following this procedure.

*Operation.*—October 18, 1945. Under continuous spinal anesthesia, an incision was made over the femoral vessels, and the sartorius muscle was retracted medially. The superficial femoral artery was exposed above the fistula and a piece of rubber tubing placed about the artery. Compression of the artery, at this point, obliterated the bruit of the fistula. The artery was then exposed below the fistula, carefully preserving the small branches, and was again controlled by rubber tubing in this location. The vessels at the site of the fistula were bound down in scar tissue. The communication was exposed by sharp dissection. With digital compression of the femoral vein above and below the fistula, the artery was cut

away from the vein. The vein was irrigated with saline and closed in a longitudinal fashion. The defect, in the artery measured 1 cm. in length, and the edges were composed of dense scar tissue. The intima of the artery was not rough. The damaged portion was excised in an elliptical fashion and the opening was closed in a transverse direction with a continuous running stitch. There was no bleeding from the suture line after release of the occluding tubes. The suture line occupied approximately three-quarters of the circumference of the vessel and caused considerable distortion at this point. However, good expansile pulsation was transmitted across the suture line. The wound was closed without drainage. After healing had taken place, oscillometry showed that there was greater pulsation on the affected side than on the normal side. Arteriogram (Fig. 22) after recovery, showed some distortion of the superficial femoral artery but preservation of the lumen. Three months after operation, the patient reported that there had been no recurrence of the aneurysm. His exercise was still limited, due to the stiffness of his knee resulting from the prolonged period of traction, and the leg tired more readily than normal.



FIG. 19 FIG. 20

FIG. 19.—Aneurysm of superficial femoral artery. Case 16. Preoperative arteriogram.

FIG. 20.—Postoperative arteriogram. Case 16. After repair of superficial femoral artery.

Case 18.—This 23-year-old male was struck by fragments from a defective mortar shell on September 24, 1945. He sustained multiple wounds of the neck, left shoulder and arm. One fragment penetrated the left arm just above the elbow and lodged beneath the skin on the medial side of the arm. Débridement of the wounds was performed and he was transferred to a Regional Hospital. While there, a pulsatile swelling in the region of the brachial artery above the elbow was noted. This increased in size. Immediately after injury he had developed a wrist drop and some weakness of the left hand. With increase in the size of the hematoma, progressive paralysis of the median nerve developed. He was admitted to this Vascular Center on October 17, 1945. No oscillations were detectible at the left wrist. Because of the increasing size of the pulsating hematoma with compression of the median nerve, he was operated upon three days after admission to this hospital.

*Operation.*—October 20, 1945: A longitudinal incision was made over the medial side of the arm above the elbow, curving slightly outward at the lower angle of the wound. Upon opening the deep fascia, some discoloration of the fat was noted. A pneumatic tourni-

quet applied about the arm was inflated and the hematoma was incised, revealing some fresh blood and old clots. The median nerve was exposed and dissected free from the aneurysm. It was found to have been flattened out as it was stretched over this tumor. Rubber tubes were passed about the brachial artery above and below the laceration in the wall, and the artery was cut from the aneurysm. The tourniquet was then released but no further bleeding occurred. The damaged portion of the arterial wall was then excised leaving only approximately one-sixth of the circumference intact. By approximating the two sections of the artery, the defect in the wall was closed in a transverse direction using a continuous stitch of No. 000000 silk through all layers of the arterial wall. There seemed to be considerable spasm of the proximal artery but at the conclusion of the operation, a good pulsatile flow could be demonstrated distal to the suture line. The cavity of the aneurysm was drained through the wound of entrance on the lateral side of the arm and the incision was closed. Immediately after operation, the color of the hand was good and a faint radial pulse was palpable. By the next day, the radial pulse had returned to its full volume and oscillometry two weeks after operation showed that the pulsations at the wrist were greater on the affected side than on the normal side. Attempted arteriography was not successful in this case but, since it was possible to obliterate the left radial pulse by pressure localized to the brachial artery just above the elbow, it was felt that the arterial repair had probably been successful.



FIG. 21



FIG. 22

FIG. 21.—Preoperative arteriogram. Case 17. Healed compound fracture of femur, with arteriovenous fistula of femoral vessels.

FIG. 22.—Postoperative arteriogram. Case 17. After repair of superficial femoral artery.

Case 19.—This 30-year-old male sustained a penetrating shelf fragment wound of the left popliteal region on June 18, 1944. In February, 1945, he noticed a thrill in the popliteal space. He was admitted to this Vascular Center on April 3, 1945. At that times there was evidence of an arteriovenous fistula involving the vessels in the upper portion of the popliteal space. Attempted arteriogram, April 20, 1945, was unsuccessful. Lumbar sympathectomy was performed on August 10, 1945. There was a considerable increase in the oscillometry at the left ankle following this procedure.

*Operation.*—October 25, 1945: Under continuous spinal anesthesia, a curved incision was made across the popliteal space. The incision was deepened along the lateral border of the semimembranosus muscle in order to expose the popliteal artery. Exposure was very difficult due to the depth of the space. The fistula proved to be at a higher level than had been anticipated. The popliteal artery was, therefore, encircled by a rubber tube below the fistula and a pneumatic tourniquet was inflated about the thigh. The artery was then dissected from the vein. Considerable retrograde bleeding took place, which was controlled with difficulty. The opening in the popliteal vein was then closed with interrupted stitches. The artery was freed-up since it was adherent to the vein and to the aneurysmal sac. Following completion of this procedure, an attempt was made to suture the opening into the artery. This was performed with interrupted stitches of No. 000 silk, the sutures being inserted both in a transverse and in a longitudinal direction in order to control residual

bleeding. At the conclusion of this procedure the pulse was not well transmitted across the suture line. The wound was closed without drainage. Following operation, although there was adequate circulation to maintain the nutrition of the tissues, the ankle pulses were not present and oscillometry, two weeks after operation, revealed a marked reduction in the pulsations at the left ankle. Although the patient was able to walk, he developed intermittent claudication after a short distance.

Case 20.—This 35-year-old male was wounded December 3, 1944, by shell fragments in both thighs. After débridement and subsequent secondary suture, the patient developed a secondary hemorrhage from a wound in the right popliteal space. Examination at that time revealed the presence of a thrill and bruit characteristic of an arteriovenous aneurysm in this region. He was admitted to this Vascular Center on March 7, 1945. Arteriography, March 23, 1945, revealed an arteriovenous fistula in the popliteal space and, in addition, there was an aneurysm on the lateral side of the popliteal artery. Because of persistent poor collateral circulation, a right lumbar sympathectomy was performed on September 13, 1945. After sympathectomy it was thought that the sac of the popliteal aneurysm became even larger than before operation.

*Operation.*—October 25, 1945: With the patient under continuous caudal anesthesia, the artery was exposed in the popliteal space above the aneurysm. It was enormously dilated. Below the fistula the artery was again considerably dilated. With compression of the popliteal artery above and below the fistula by rubber tubing, the bruit was completely abolished. Accordingly, the pneumatic tourniquet which had previously been placed about the upper part of the thigh, was inflated and the artery was cut away from the vein. There was considerable back bleeding from the venous side, which was controlled by digital pressure until the opening into the vein could be sutured. In addition to the fistula between the popliteal artery and vein, a small aneurysm, 1 cm. in diameter, was found on the medial side of the popliteal artery. After irrigation of the lumen of the artery with normal saline solution, it was found that, although the artery was considerably dilated both above and below the fistula, the wall seemed to be composed of good tissue and the intima was smooth. The two defects in the arterial wall were closed separately with No. 000 silk. After release of the pneumatic tourniquet, good expansile pulsation of the artery distal to the suture line was apparent. The incision was closed without drainage. Immediately after operation, the posterial tibial pulse was palpable and the color of the foot was excellent. Oscillometry after recovery from operation was almost normal. An arteriogram (Fig. 23) showed that the continuity of the artery had been preserved. However, there was considerable dilitation both proximal and distal to the point of repair. A phlebogram taken on the same day showed that the popliteal vein had been occluded. Three months after operation, he reported that there had been no recurrence of the aneurysm, but that he had some swelling of the foot and lower leg with dependency. He also developed some cramps in his upper calf on climbing hills.

Case 21.—This 21-year-old male was wounded on May 8, 1945. A 25-caliber bullet passed through the midportion of both thighs. He developed drop foot and anesthesia of the left foot, probably on an ischemic basis. Sometime after injury, during the process of evacuation, he noted a thrill in the left thigh. Upon admission to this Vascular Center, June 20, 1945, there were characteristic signs of an arteriovenous fistula involving the midportion of the left superficial femoral vessels. Arteriography, July 20, 1945, confirmed the diagnosis. Oscillometry showed a considerable reduction in the amplitude of pulsations at the left ankle but because of adequate collateral circulation and the possibility of arterial repair, sympathectomy was not performed. Satisfactory recovery from the nerve lesion was apparent.

*Operation.*—October 29, 1945: Under continuous spinal anesthesia, the superficial femoral artery was exposed in the midthigh and was occluded by rubber tubing passed above and below the fistula. The artery was then dissected free from the vein and the bleeding controlled by digital pressure until the vein could be sutured in a longitudinal fashion.

The damaged portion of the arterial wall was then excised and the defect was closed in a transverse direction. Good expansile flow took place after release of the rubber tubing. The wound was closed without drainage. Postoperatively, there were no complications and the pulses at the ankle were excellent. Oscillometry revealed equal pulsation of the arteries at both ankles. Arteriography three weeks after operation demonstrated the patency of the artery and phlebography showed that the vein was not obstructed. Three months later, he reported that the leg became weak after any extensive exercise, but that there had been no recurrence of the aneurysm. Since he also had partial paralysis of the sciatic nerve with moderate flexion deformity of the left knee, the residual symptoms may be more on a neurologic than a vascular basis.



FIG. 23. — Postoperative arteriogram. Case 20. There is considerable dilatation of the femoral artery above and the popliteal artery below the site of the former arteriovenous fistula.

Case 22.—This 33-year-old male was struck by a shell fragment in the right thigh, March 18, 1945, and sustained a laceration of the popliteal nerve. He was operated upon in a Forward Area, April 21, 1945, and a neurorrhaphy performed. At this time an arteriovenous fistula of the right popliteal artery and vein was discovered. At the time of admission to this Vascular Center, July 4, 1945, he already showed evidence of recovery in nerve function. There were classical signs of an arteriovenous fistula involving the vessels of the popliteal space. Attempts to visualize the aneurysm by arteriography were unsuccessful. A lumbar sympathectomy was performed on July 30, 1945. Following this operation there was improvement in the collateral circulation.

*Operation.*—November 5, 1945.—Under continuous caudal anesthesia, the popliteal artery was exposed in the upper portion of the popliteal space by a longitudinal incision just lateral to the tendon of the semimembranosus muscle. The artery was greatly dilated. It was controlled by a piece of rubber tubing attached to a Bethune tourniquet. Compression of the artery at this point now obliterated the thrill in the aneurysm although the bruit still persisted. Incision was then made on the lateral side of the popliteal space extending from behind the head of the fibula upward medial to the biceps tendon. The common peroneal nerve was exposed and followed to its junction with the posterior tibial. Tantalum foil, which encased the posterial tibial nerve for a distance of 2.5 inches, was removed. The peroneal nerve was retracted laterally and the posterior tibial medially to expose a greatly dilated popliteal vein. Numerous branches were divided and ligated and the vein was retracted medially to expose the popliteal artery below the fistula. This artery was now compressed by a piece of rubber tubing. The popliteal vein was controlled by sections of rubber tubing, above and below the fistula. With all four vessels now compressed, there was still audible a faint continuous bruit, with excessive pressure within the popliteal vein. Further dissection disclosed a small aneurysmal sac, approximately 2 cm. in diameter. From the apex of this sac the inferior lateral geniculate artery was derived. After controlling the retrograde circulation through this vessel, the popliteal artery was dissected free from the vein. The opening into the vein measured approximately 1.5 cm. in length and was closed in a transverse direction by a running stitch of No. 000 silk. The popliteal artery was badly scarred and bound down in the region of the aneurysm. It was dissected free from the sac. There were two defects in the arterial wall, one which measured 1 cm. in diameter where the communication with the vein had been located, and a second larger defect at the site of the aneurysm. The damaged portion of the arterial wall was cut away transforming the two holes into one large defect, which occupied three-fifths of the circumference of the vessel.

The intima and media of the popliteal artery appeared normal and, accordingly, a transverse suture was performed using No. 000 black silk. Thirty minutes after completion of the procedure, excellent pulsation was present below the suture line. The wound was closed without drainage. Convalescence was uneventful and oscillations at the two ankles were equal. Arteriography was not successful. Three months after operation, the patient reported that there had been no recurrence of the arteriovenous fistula and that there was satisfactory progress in the regeneration of the nerve. He was still troubled with swelling above the ankle, but the circulation to the leg appeared excellent.

COMMENT.—Of the 17 cases in which transverse repair of the artery was attempted, it was successful in 15. Restoration of the continuity of the artery was demonstrable by arteriogram in ten of these cases and in the other five by the persistence of normal pulses distal to the site of repair. Of the two unsuccessful attempts, thrombosis occurred at the suture line in one patient (Case 19), but this was in part due to faulty technic in not obtaining adequate control of the artery above the fistula. In the second individual (Case 16), repair was attempted of an arterial aneurysm. Scar tissue of the aneurysmal wall was used to reinforce the suture line. The patient has reported recurrence of his aneurysm. It may well be that this scar tissue has given way, permitting this new aneurysm to form.

DISCUSSION.—The value of arterial repair in the treatment of aneurysms and arteriovenous fistulae may be questioned. Since the incidence of gangrene after ligation of major arteries of the extremities in the treatment of these lesions is negligible, the question may rightly be raised: "Why subject the patient to the risk of repair?" While it is true that gangrene is rare after excision of these injured arteries the end-results are often not favorable. Bigger[2] has written: "In the literature dealing with the treatment of traumatic vascular lesions of important blood vessels, much is said, and properly, about the cure of the lesion and the avoidance of acute ischemia and gangrene, but remarkably little consideration is given to the permanent reduction of blood supply to the tissues, especially the muscles, distal to the lesion." While it is true that after excision the development of collateral circulation will usually suffice to care for the metabolic requirements of the tissues at rest, it is only rarely that some impairment of circulation is not noted.

In reply to a questionnaire sent to the patients from this Vascular Center in whom either the popliteal or the femoral artery had been ligated for an arteriovenous fistula during the past year, nine out of 12 individuals complained of restriction in their activities. Intermittent claudication came on after walking from two to five blocks. In comparison, of 11 patients in the present series after repair of popliteal or femoral arteries for arteriovenous aneurysms, only two complained of intermittent claudication and symptoms came on in these patients only after walking six to eight blocks.

Oscillometric readings before operation in 12 patients were on the average 2.77 units on the affected side and 4.44 on the opposite normal side. After arterial repair the average oscillations of these same patients were 3.85 on the affected side and 3.79 on the normal side. By comparison, in ten patients

in whom the major artery was ligated the average oscillometric readings before operation were 2.72 on the affected with 5.0 on the normal side. After operation the values were 0.75 and 4.0, respectively. Arterial repair, therefore, increased the oscillometric readings from an expected 0.75 to an average of 3.85 units. It is well known that the circulation may be quite adequate for tissue nutrition even in the absence of arterial oscillations but the preservation of pulsatile arterial flow through the major arteries is naturally to be preferred.

Even granted that preservation of the continuity of the artery is to be preferred the question may still be brought up of the possible risk to the patient. The dangers of hemorrhage or infection do not appear to be increased by arterial repair. In only one patient (Case 4) was serious infection encountered. Hemorrhage did not occur in any case in this series. The major objection to arterial repair in the past has been the recurrence of the fistula or the development of a false aneurysm close to the site of repair. In three of the five cases reported by Pemberton and Black,[7] ligation of the communication or restorative endaneurysmorrhaphy was followed by recurrence of the fistula. One patient in our series (Case 3) developed recurrence after transvenous suture. Of more significance is the possibility of the development of a false arterial aneurysm after closure of the fistula. Direct measurements of pressures within arteriovenous fistulae[18] in 11 patients have shown an average mean pressure of only 40 mm. of mercury. By comparison, in 12 patients with arterial aneurysms, the average mean pressure was 84 mm. of mercury. According to these figures then, closure of the communication between the artery and vein should approximately double the mean pressure. It is quite to be expected that any weak point in the arterial wall would give way with this increase in pressure.

The incidence of additional points of damage of the arterial wall in the presence of arteriovenous fistulae is high. Two defects, one communicating with the main vein and the other with an aneurysmal cavity or another vein, were found in six cases in this series and three venous communications were present in one patient (Case 3). Reid and McGuire[8] have reported one case in which a second communication was overlooked at the original operation and Holman[9] has observed a second case. Only by completely isolating the artery from the surrounding tissues can the presence of additional communications or damaged areas of the arterial wall be discovered. Generalized dilation of the artery to form a fusiform aneurysm following closure of an arteriovenous fistula has been described by Reid,[6] and by Bigger.[2] In each of their cases the fistula was of long duration with marked degenerative changes in the arterial wall. The average duration of the fistula in the patients reported in this series was only eight months and the longest-standing case was 14 months. Dilatation of the artery, especially proximal to the fistula, was frequently observed (Case 21) but rarely was there calcification. No attempt at repair was made in the presence of degenerative changes.

After careful inspection of the arterial wall the damaged portion was generally removed. In 11 cases in the present group a portion of the arterial

wall was excised. Particular emphasis was placed on this procedure since it is believed that only the presence of normal arterial wall composed of muscular and elastic tissue can prevent subsequent dilatation. Although the use of the wall of the sac or a segment of vein to reconstruct the arterial wall has been advocated by Matas[19] it does not seem likely that this material which is largely composed of fibrous tissue can withstand the increased pressure. Makins[1] has condemned the use of such flaps in the repair of arterial defects. The fact that such tissue is not an effective limiting barrier is shown by the tendency of aneurysms to expand. To use scar tissue to buttress the line of suture affords only a false sense of security. The recurrence of the arterial aneurysm in Case 16 is illustrative of the futility of using anything but normal arterial wall in the repair.

After excision of part of the arterial wall the resultant defect must be closed by approximation of the edges of the incision. Learmouth[17] has stated that an artery cannot be stretched. In the presence of an arteriovenous fistula, however, the artery, especially the proximal portion, has generally become so dilated that sufficient length is already available. Approximation is readily obtained by means of the rubber tubing which is used to occlude the artery above and below the fistula (See Fig. 10).

It has generally been found desirable to use any sound portion of the arterial wall, even to one-sixth of the circumference (Case 18), rather than to perform a complete transsection with end-to-end anastomosis. Mobilization of the artery may be impossible due to important branches. According to Learmouth[17] "the length over which vessels can be freed and mobilized is governed by the points of origin of branches which are indispensable for the collateral supply, if the repair is not successful." In no case was a significant collateral artery sacrificed in order to attempt repair of the major vessel.

Holman[18] has emphasized the fact that arterial repair in the presence of arteriovenous fistula depends upon the "ability to control completely all bleeding, either by the tourniquet proximal to the lesion, or by numerous well-placed bulldog arterial clamps, as described by Matas." Linton[20] has advocated the use of the Bethune tourniquet in order to control the deeper-seated major blood vessels. The use of rubber tubing has been most satisfactory in our cases and, when split, it may be fitted to a Bethune tourniquet with equally good results. After surrounding the vessel with the section of rubber tubing (cf. Fig. 10) it has been clamped close to the arterial wall with fine curved mosquito hemostats. No damage to the arterial wall has been observed and approximation of the edges of the incised vessel has been facilitated.

Complete control of the arterial supply to an arteriovenous fistula is essential for repair. Failure in the one case in which this was not achieved (Case 19) serves to emphasize the importance of this procedure. The use of a sterile stethescope at the time of operation has been found to be invaluable in confirming the completeness of the control of the arterial component. Occlusion of the principal afferent and efferent arteries alone may not suffice. Persis-

tence of a continuous bruit signifies that some additional arterial supply is present. As long as there is arterial blood passing through the fistula, to sever the connection is hazardous.

Complete control of the venous component facilitates the repair but may require prolonged and tedious dissection and may result in destruction of collateral vessels. In eight patients both arteries and veins were secured proximal and distal to the fistula by segments of tubing and heavy thread. In seven patients, however, control of the arteries alone was achieved. At the moment of severing the connection between the artery and the vein or aneurysmal sac, digital pressure was used to control the venous bleeding. Suture of the open vein was then readily accomplished. In five other cases, after the afferent and efferent arteries had been isolated a pneumatic tourniquet, which had previously been placed at a higher level about the extremity, was inflated. This procedure was not especially useful since the venous system in the presence of an arteriovenous fistula was capacious and already full of blood. Retrograde bleeding generally necessitated digital pressure in addition to the proximal tourniquet. Frequently the venous pressure appeared to be even higher than without the tourniquet.

Once the artery has been disconnected the opening into the vein can be closed longitudinally with a running stitch. This procedure was employed mainly for the purpose of simplicity in dealing with the venous component of the fistula since it is rarely necessary to repair the vein. The continuity of the left innominate vein in Case 4 was preserved especially since the thoracic duct emptied into it. Phlebography after suture of the vein in 12 cases showed the vein to be patent in six and obstructed in the other six patients. In an additional five cases in which the vein was sutured, even though arterial repair could not be performed, patency was demonstrable in three and thrombosis in two. No instance of thrombophlebitis or pulmonary embolism was encountered. These complications would, therefore, appear to be no more of a hazard from suture of the vein than from its ligation since cases of embolism have been reported by Reid,[6] and by Linton and White[21] after ligation.

Arteriography has been helpful in the study of patients with arteriovenous fistulae. Before operation it has served in the accurate localization of the lesion and in demonstrating the location of important collateral vessels. Again, it has helped to show the presence of an aneurysmal sac (Case 5). In the presence of such a sac considerable destruction of arterial wall can be anticipated with consequent reduction in the chances of successful repair. Following operation arteriograms have been useful in disclosing the true state of continuity of the artery (Case 5). In addition they may show early evidence of general dilatation (Case 20) or satisfactory progress of the local lesion (Case 10).

The rôle of sympathectomy in the repair of arterial lesions is not clear. Thirteen of the patients in this series were treated by prophylactic sympathectomy before operation on the arterial lesion. Of this number two attempted

repairs failed. Sympathectomy was not performed in ten patients. Arterial thrombosis occurred in only one of these cases. It is possible that sympathectomy might have prevented arterial spasm though Homans[22] has reported that sympathetic procaine block has not been successful in relieving traumatic arterial spasm. It is probable that a swift flow of blood prevents thrombosis at the suture line. Possibly sympathectomy may have promoted increased volume flow of blood and in this way have improved the chances of successful repair.

Transverse closure of the defect in the arterial wall may produce distortion and turbulence of the blood stream. In fact, auscultation over the vessel at the suture line reveals a loud sharp systolic murmur and this sound is even audible through the skin and soft tissues after healing has taken place. Without a diastolic component it has no significance. Although distortion is produced by the transverse closure it is likely that the greater diameter at this point prevents thrombosis and in this way increases the likelihood of successful repair.

## SUMMARY

Arterial repair was attempted in the treatment of 23 aneurysms and arteriovenous fistulae. Success was demonstrable either by arteriography or by the presence of normal peripheral arterial pulsations in 18 of these attempts. In one case, recurrence of an arterial aneurysm was subsequently reported by the patient. In a second patient, recurrence of an arteriovenous fistula followed transvenous suture. Subsequent excision of the lesion was necessary. Thrombosis at the suture line occurred in three patients but the collateral circulation proved sufficient to prevent gangrene. Repair of the defect in the wall of the vein was performed on 18 occasions. Phlebography in 12 of these cases after recovery demonstrated the patency of the vein in six patients but in six others postoperative studies showed the vein to be occluded. No instance of thrombophlebitis or pulmonary embolism was encountered. Transverse suture of the defect in the arterial wall after excision of the damaged portion has been found more satisfactory than longitudinal suture, end-to-end anastomosis or transvenous repair. Oscillometry, after arterial repair, has demonstrated marked improvement in pulsatile circulation in patients after repair of arterial lesions in comparison to a control group who were treated by quadruple ligation and excision of the arteriovenous fistula.

The functional capacity, especially as shown by freedom from intermittent claudication, is increased in patients when the continuity of the major artery to the extremity is preserved.

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DISCUSSION.—DR. RUDOLPH MATAS, New Orleans, La.: It appears to me that the tendency of operators in this war has been to disregard the conservative treatment of the arteriovenous aneurysms. This is due chiefly to a general belief that the collateral circulation in the arteriovenous aneurysms is so well-developed when the operation is delayed, that conservative methods directed toward the saving of the artery are superfluous. While I agree that in many and, perhaps, the majority of the "mature" (long-standing) A-V aneurysms the fistulous tract and attached vessels may be safely excised or ligated, this is not true of many cases in which the sacrifice of the artery may be followed by disastrous consequences — this being particularly true of the carotid and popliteal and common femoral fistulae, especially when the operations are performed too soon after the fistula has been established.

Fistulous communications between an artery and contiguous vein caused by punctures, stabs or the penetration of small projectiles of high velocity; and sharp metallic splinters of exploding shells and bombs in which the artery is not damaged, dilated or deformed, are particularly favorable for repair and cure by the method of *transvenous suture* in which the fistula is exposed, and closed by suturing the orifice from the venous side, with conservation of the artery and sacrifice of the vein.

When the artery is damaged in any way, the problem of repair becomes more difficult, and other devices besides the transvenous and the intrasaccular suture must be sought. In the great majority, the tests for an adequate collateral circulation will show that by prolonging the delay in operating, surgical interference may become safe by an ultimate development of the collaterals. When complications arise, such as cardiac failure from the fistula, that call for its quick closure, and the circulation is inadequate, the excision of the fistulous tract with a circular anastomosis of the artery, is in order, to maintain the arterial circulation. This is a procedure that is, indeed, seldom required. I have never had to resort to it in my large experience. Doctor Elkin, likewise, states that he has never had to apply a secondary arteriorrhaphy for an excised A-V aneurysm. The German surgeons did resort to it quite often in World War I. There can be no doubt that in modern warfare, the indications for an immediate anastomosis for divided or obliterated arteries as the popliteal, femoral and carotids, do occur quite often, but the conditions for reparative and reconstructive operations on the blood vessels are too rare and difficult on the battlefield.

In civilian practice, where there is less haste, the opportunities for reparative surgery of the arteries and arteriovenous aneurysms are more frequent, but are seldom utilized by men who have been trained to perform radical excisions or quadruple ligatures in A-V fistulae.

Doctor Freeman, always striving at conservatism and repair, has gone further than I, in my civilian practice, with A-V aneurysms. For, in suitable cases he detaches the inosculating vessels, closes the lateral wound in the vein, and then divides the artery through the fistulous tract with a segment of the damaged artery. Finally, he restores the arterial circulation by doing an end-to-end anastomosis. Doctor Freeman has certainly had a very remarkable experience. The fact that in 24 cases in which a circular arteriorrhaphy was performed, 20 were successful in maintaining the arterial circulation, speaks eloquently for a high degree of technical skill with the needle which is rare among otherwise skillful surgeons. Doctor Freeman is entitled to praise and congratulations not only for his technical skill but for his brilliant demonstration of the efficiency of repair and conservatism in arteriovenous surgery.

With the kind permission of the Chair, I will now avail myself of a brief interval to exhibit lantern slides taken from patients in my own practice, in which transvenous suture methods originally devised by Bickham and myself, 43 years ago, for the cure of arteriovenous aneurysms will be exhibited in their application to A-V aneurysms of the innominate, subclavian, carotid, external iliac, femoral and popliteal.

DR. ISAAC A. BIGGER, Richmond, Va.: One patient with femoral fistula developed evidence of vascular insufficiency, even though the distal arterial segment pulsated strongly following resection of the fistulous area. This suggests that there may be regression of the collateral bed after removal of a fistula.

DR. NORMAN E. FREEMAN, Auburn, Calif. (closing): I wish to thank Doctor Matas and Doctor Bigger for their valuable comments. In regard to the transvenous closure of a false communication between an artery and vein, I should like to re-emphasize the danger of overlooking some additional opening or weak point in the arterial wall. With the rise in arterial pressure which occurs as soon as the fistula is closed, there is a real possibility that an additional, and possibly unsuspected, defect in the muscular and elastic coats of the arterial wall will give way, leading to the development of an arterial aneurysm.

As to the possibility of regression in the collateral bed after removal of a fistula, that would hardly seem likely in the presence of impaired circulation. Although the exact mechanism is obscure there is evidence that the stimulus for the development of collateral circulation is closely related to the need for blood flow. And even when

a superabundant circulation is produced by closure of an arteriovenous fistula, the extracollateral channels do not disappear. We have studied by means of arteriography the distribution of arterial pathways following spontaneous closure of arteriovenous fistulae in four patients. Even though the circulation through the main artery is restored by this spontaneous closure, one can still observe the dilated and tortuous collateral vessels filled with radioopaque dye. Oscillometric readings, following restoration of the continuity of the main vessel, will frequently be greater immediately after operation than some weeks later. This observation would suggest that some contraction of the vascular bed occurred but not in the presence of superabundant flow. The presence of symptoms of arterial insufficiency after excision of an arteriovenous fistula, in spite of a positive Henle-Coenen sign, *i.e.*, pulsation of the distal end of the artery, might be interpreted as further evidence for the concept which Doctor Bigger has advanced. Although the circulation is adequate when the part is at rest, the collateral vessels do not have sufficient capacity to expand to care for the metabolic demands created by exercise.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933 Of ANNALS OF SURGERY, published monthly at Philadelphia, Pa., as of November 1, 1946.

State of Pennsylvania } ss.
County of Philadelphia }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Ellis W. Bacon, who, having been duly sworn according to law, deposes and says that he is the Treasurer of the ANNALS OF SURGERY and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and [illegible] blisher, editor, managing editor, and business managers are: Publisher, J. [illegible] any, E. Washington Square, Philadelphia, Pa. Editor, Dr. Walter E. Lee, [illegible] Board, 1833 Pine Street, Philadelphia, Pa. Managing Editor, Dr. James T. Pilcher, 121 Gates Avenue, Brooklyn, New York; Business Manager, O. T. Leeman, E. Washington Square, Philadelphia 5, Pa.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.) J. B. Lippincott Company, E. Washington Square, Philadelphia, Pa.; Ellis W. Bacon, Wallingford, Pa.; Sarah L. Biddle, Bethayres, Pa.; Bertram Lippincott, Penllyn, Pa.; Joseph W. Lippincott, Bertram Lippincott and the Pennsylvania Company for Insurances on Lives and Granting Annuities, Trustees under Will of J. Bertram Lippincott, Philadelphia, Pa.; J. W. Lippincott, Bethayres, Pa.; Marianna L. O'Neill, Rydal, Pa.; Pennsylvania Company for Insurances on Lives and Granting Annuities, Trustee Estate of Craige Lippincott, Philadelphia, Pa.; Fidelity Philadelphia Trust Company, Trustee Estate of Walter Lippincott, Philadelphia, Pa.; Howard K. Bauernfeind, Chicago, Illinois; George Stevens, Kingston, N. J.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

[Signed] ELLIS W. BACON.

Affirmed to and subscribed before me this 30th day of September, 1946.
[Seal] HARRY J. BEARD.

(My commission expires March 5, 1949.)

# ROENTGENOLOGIC KYMOGRAPHIC STUDIES OF THE HEART IN THE PRESENCE OF AN ARTERIOVENOUS FISTULA AND THEIR INTERPRETATION*

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SAN FRANCISCO, CALIFORNIA

THE EFFECTS of an arteriovenous fistula upon the heart and circulation have been the subject of numerous clinical observations,[1-5] much philosophical discussion,[6-14] and extensive experimentation.[15-20] Often the observed facts have seemed contradictory and their explanation has, therefore, been elusive. More often than not, observations have been recorded without attempts at explanation. But the mere recording of observed facts is not as important as determining their sequence and their *"raison d'etre."* Having determined a logical explanation for certain phenomena,[21] one should seek constantly to verify or disprove it. Such an opportunity was provided recently by two cases of arteriovenous fistula in which cardiac silhouettes were obtained by roentgenologic kymography. Very significant changes in the silhouette occurred, providing important information as to the sequence of events that occurs in the circulatory apparatus on closing or opening a fistula. Moreover, instructive evidence was obtained applicable to the explanation of the almost mysterious retardation in pulse rate that accompanies the closure of a large fistula.[22]

## CASE REPORTS

CASE 1.—Fifteen years ago, J. P., age 52, was shot through the soft tissues of the left popliteal space. Two operations were performed within the following week, accompanied by a great loss of blood at each operation. Despite an infection, recovery occurred without other complications. His general health had been excellent until the two years preceding his admission to the hospital in September, 1945, when he had noted gradually increasing shortness of breath and weakness and swelling of his left leg (Fig. 1). A palpable thrill had been present along the course of the femoral vessels ever since the accident. Several ulcers had appeared on the inner aspect of the left ankle, the last one having healed about four years ago.

Physical examination revealed an enlargement of the heart over which one could hear a rough, blowing systolic murmur particularly in the pulmonic area.

The left leg was definitely larger than the right, with prominent varicosities of thigh and leg. The left femoral artery below the inguinal ligament was greatly dilated and remarkably tortuous down to the popliteal space. Along its course was a continuous palpable thrill and audible bruit, so intense in the midthigh that one was almost led to believe that the communication lay here rather than in the popliteal space; however, pressure in the latter area over the bullet track completely controlled the thrill and bruit proximal to it, thus eliminating the possibility of an abnormal communication other than that in the popliteal space. The intense thrill

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

in the thigh was ascribed to the eddies set up in the large proximal vein by blood flowing rapidly through the large popliteal fistula.

At operation, October 2, 1945, performed during the first half without a tourniquet,[23] the fistula was found to be a direct lateral communication between the popliteal artery and vein. The proximal artery was 2.5 cm. in diameter, whereas distal to the fistula the artery was only 0.7 cm. in diameter. The popliteal vein both proximal and distal to the fistula was 2.8 cm. in diameter.



FIG. 1. — Case 1: Photograph in presence of large left popliteal fistula showing large varicosities beyond the fistula, large dilated heart, and marked tortuous dilatation of artery proximal to fistula.

The Henle-Coenen[24, 25] phenomenon was absent: *i.e.*, when the artery proximal to the opening was closed, there was no pulsation either in the artery just distal to the opening, or in the posterior tibial artery at the ankle. Hence restoration of the artery was considered desirable in order to insure an adequate circulation in the leg beyond the fistula. When the Henle-Coenen phenomenon is present, *i.e.*, when the artery pulsates distal to the site of closure, we may assume that the arterial collateral circulation is adequate for the life of the limb, and the artery may be divided with impunity. Since pulsating vessels are more easily identified and mobilized than are collapsed vessels, the artery and vein both proximal and distal to the fistula were isolated in the distended state. Following the inflation of a pneumatic tourniquet on the upper thigh the vein was opened longitudinally just opposite the fistula, which in the collapsed state of the vessels was found to measure 1.5 cm. in diameter. As the collapsed artery was half its original size, one may infer that the fistula when transmitting blood was at least 2 to 2.5 cm. in diameter. The rent in the artery was closed with a running suture of doubled silk approximating the edges of the arterial opening, reinforced with several interrupted sutures of silk. The posterior leaf of the incised venous wall was sutured to lie over the line of the arterial closure, and the anterior leaf of the vein was imbricated over the posterior leaf. The vein proximal to the fistula was permanently ligated, whereas below the fistula the vein was both ligated and divided. Deflation of the thigh tourniquet was followed by vigorous pulsation in the posterior tibial and dorsalis pedis arteries.

The wound healed *per primam.* There was marked localized tenderness over the dilated tortuous artery of the thigh for several days, which gradually subsided without evidence of clotting.

CASE 2.—A 20-year-old army recruit was seen in brief consultation for a greatly swollen right thigh and lower leg incident to an arteriovenous fistula of the common femoral vessels following a gunshot wound three years previously. Despite the greatly swollen leg and a dilated heart, he had been inducted into the service, but since he refused an operation for the elimination of the fistula, he was discharged from the army. Before his discharge, kymographic studies were made revealing a marked widening of the aortic arch and additional dilatation of the already dilated heart on closing the fistula (Fig. 2). General blood pressure rose from 110/60 to 150/84 on closing the fistula accompanied by a drop in pulse rate from 76 to 48. This increase in pressure and resulting retardation in pulse indicated a considerable increase in total blood volume. It is interesting to record that his head felt "full" and his chest "tight," when the fistula was closed, suggesting a filling-up of the arterial vessels in these two areas when the fistula was temporarily eliminated from the circulatory bed.

The following special studies in Case 1 before and after operation were of more than usual interest:

*Blood Pressure.*—Compression of the artery anywhere in the thigh proximal to the popliteal area caused an elevation of pressure from 100/60 to 160/80 for several beats, subsiding promptly to 146/72 as long as the fistula was closed (Fig. 3). The rise in pressure was accompanied by a marked retardation in pulse from 75 to 48. Both pressure and pulse returned to normal on release of the compression. At

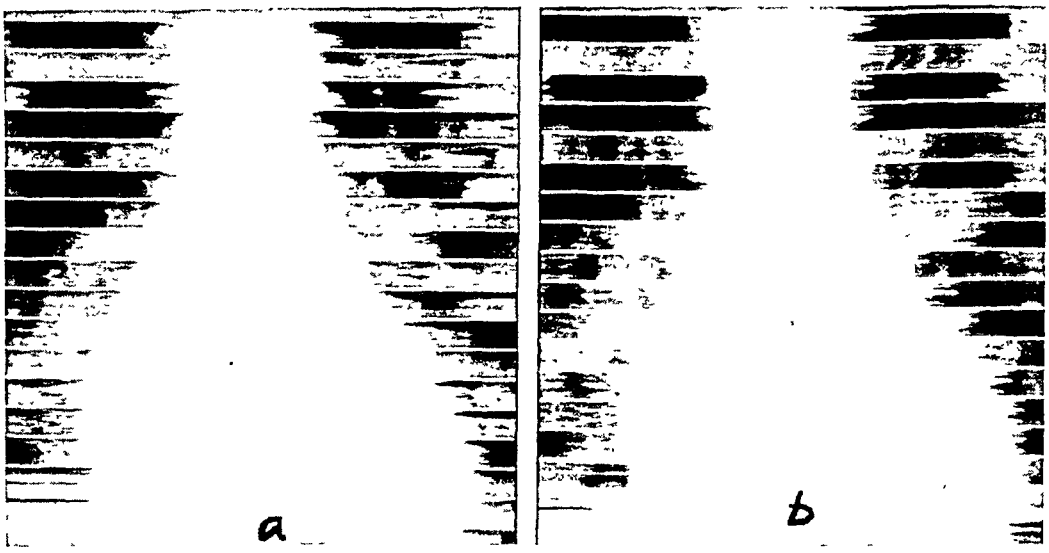



FIG. 2.—Case 2: (A) Roentgenographic kymogram in which during first half of exposure a femoral fistula was closed, and during the second half it was open.
(B) Roentgenographic kymogram in which during first half of the exposure, the fistula was open and during second half of exposure it was closed. Note marked widening of aortic arch during closure of fistula and evidence of further distention of an already dilated left ventricle on closing the fistula.

operation, closure of the fistula by digital pressure caused a rise in blood pressure from 120/80 to 170/100, and a slowing of pulse from 80 to 48. Following operation, the blood pressure which formerly fluctuated around 100 to 110 systolic and 60 to 70 diastolic was consistently higher: 130/90 in the first few days, 120/80 thereafter, with a resting pulse of 65 to 75.

*Blood Volume.*—On September 24, 1945, blood volume studies (Fig. 4) were made by Dr. James Hopper, Jr., of the University of California:

Patient's weight 58.5 kg.; height 172 cm. CO method: 6,100 cc. blood volume; 3,420 cc. plasma; 2,680 cc. cells; T 1824 dye: 6,000 cc. blood volume; 3,370 cc. plasma; 2,630 cc. cells. Packed cell volume 44 per cent. Blood serum proteins 6.8 Gm. per cent. These studies were repeated on October 23, 1945, three weeks after operation: CO method: 5,130 cc. blood volume; 3,080 cc. plasma; 2,050 cc. cells; T 1824 dye: 5,250 cc. blood volume; 3,150 cc. plasma; 2,100 cc. cells. Packed cell volume 40 per cent. Blood serum proteins 7.45 Gm. per cent.

*Fluid Balance.*—For the four days preceding operation the total fluid intake was 13,930 cc. with a urinary output of 11,940 cc. During the four days following operation the fluid intake totaled 6,810 cc. with a urinary output of 9,620 cc. This increased output over intake following operation is part of the readjustment and reduction in total blood volume that occurs following permanent elimination of a fistula.

*Electrocardiography.*—(Fig. 5) Before atropinization: pulse 71; sinus rhythm; small Q-wave in all leads; T normal; at the pulmonic area a systolic murmur. On closing the fistula, the pulse rate dropped to 41, the intensity both of the first sound and of the pulmonic murmur was decreased, but the second sound was increased; the amplitude of the brachial pulse was diminished and a plateau of high pressure appeared at once, several beats *before* the retardation in pulse.

After atropine gr. 1/50 subcutaneously: on closing the fistula retardation in

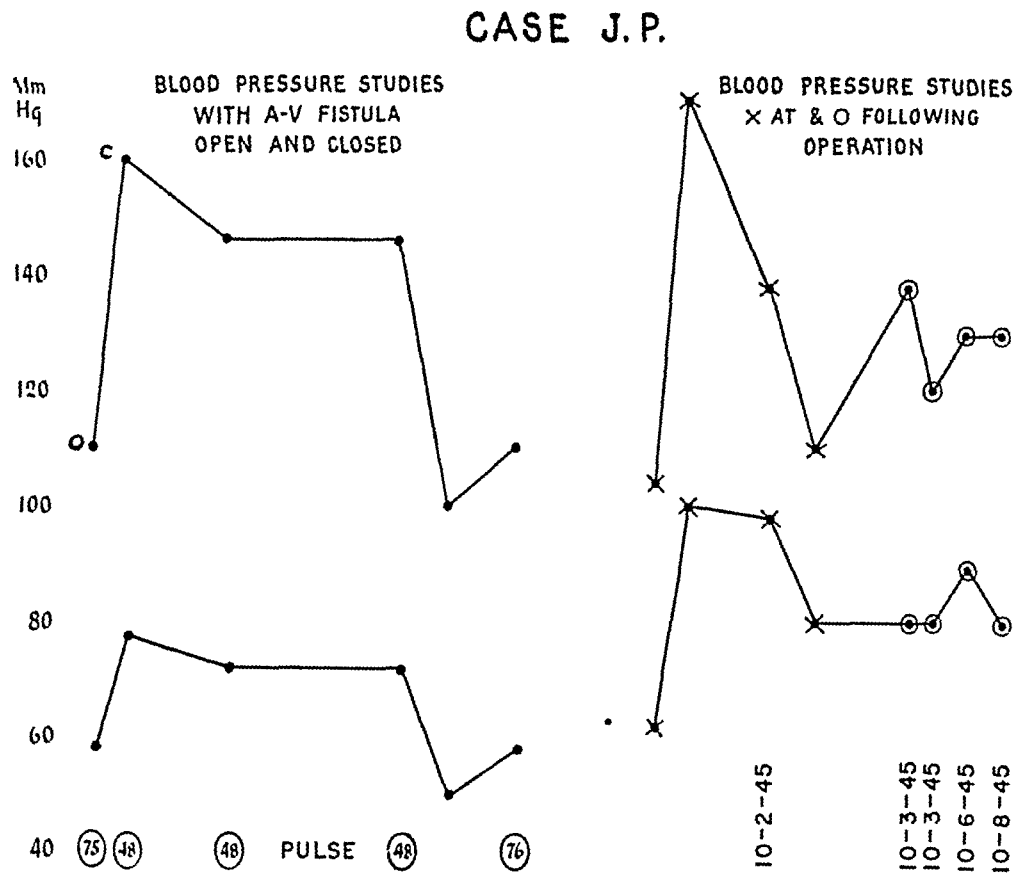



FIG. 3.—Closure of a large peripheral fistula produces a characteristic great rise in blood pressure for several beats only, subsiding promptly to a lower level of increased pressure as long as the fistula remains closed, dropping acutely when the fistula is opened, followed by prompt recovery to its usual level. The increase in pressure is accompanied by a marked retardation in pulse as long as the fistula remains closed. Following elimination of fistula by operation, the systolic pressure is temporarily elevated, the diastolic pressure is permanently increased.

pulse rate was practically absent, but the increase in blood pressure occurred as usual and the brachial pulse wave showed a diminution in amplitude and a plateau of increased pressure as before.

*Teleroentgenography.*—(Fig. 6) Before operation the heart measured 15.3 cm. in transverse diameter, and the aortic diameter measured 6.0 cm. Blood vessel markings in the lungs were very prominent indicating a greatly increased flow through the pulmonary vessels in the presence of the open fistula. Twenty days after operation, the heart measured 14.2 cm. in diameter and 96 days after operation, 12.3 cm.

*Roentgenologic Kymography.*—These studies yielded important and instructive observations. Ten-second kymograms were made, in one of which the fistula was open during the first five seconds of exposure and closed by digital pressure during the next five seconds of exposure. Another ten-second kymogram was made, in

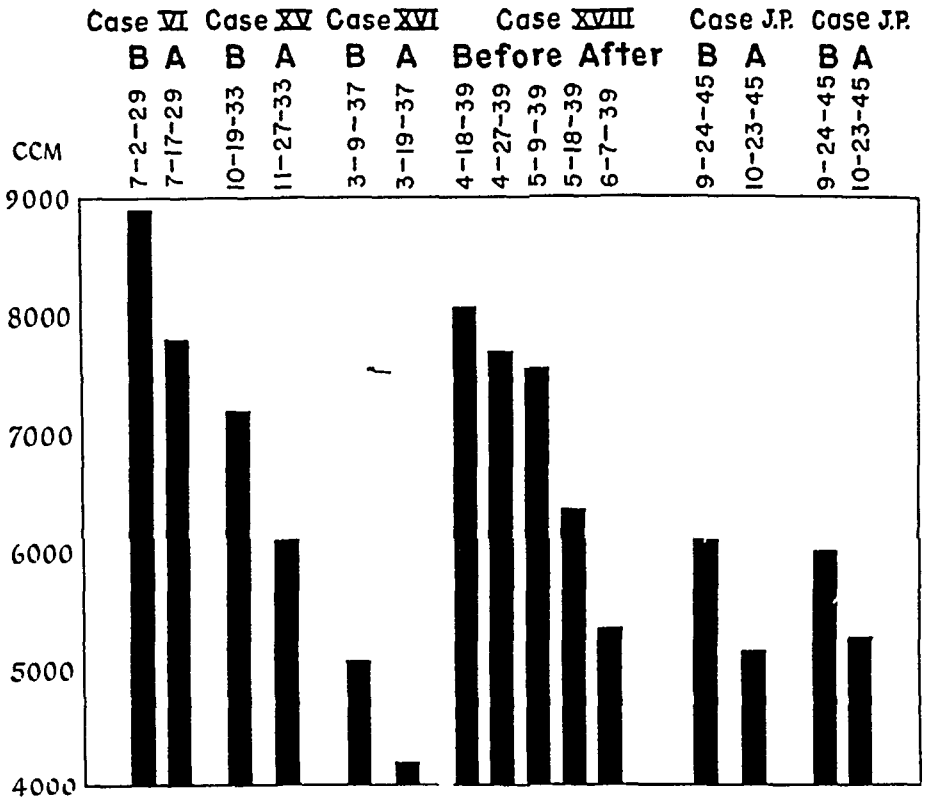



FIG. 4.—Clinical studies have corroborated experimental observations that there is a considerable increase in total blood volume in the presence of a peripheral fistula as shown by a decrease in total blood volume when the fistula was eliminated by operation: 1,000 cc. in Case 6; 1,200 cc. in Case 15; 800 cc. in Case 16; 2,700 cc. in Case 18, characterized by cardiac decompensation due to the fistula; 1,000 cc. in Case J. P.

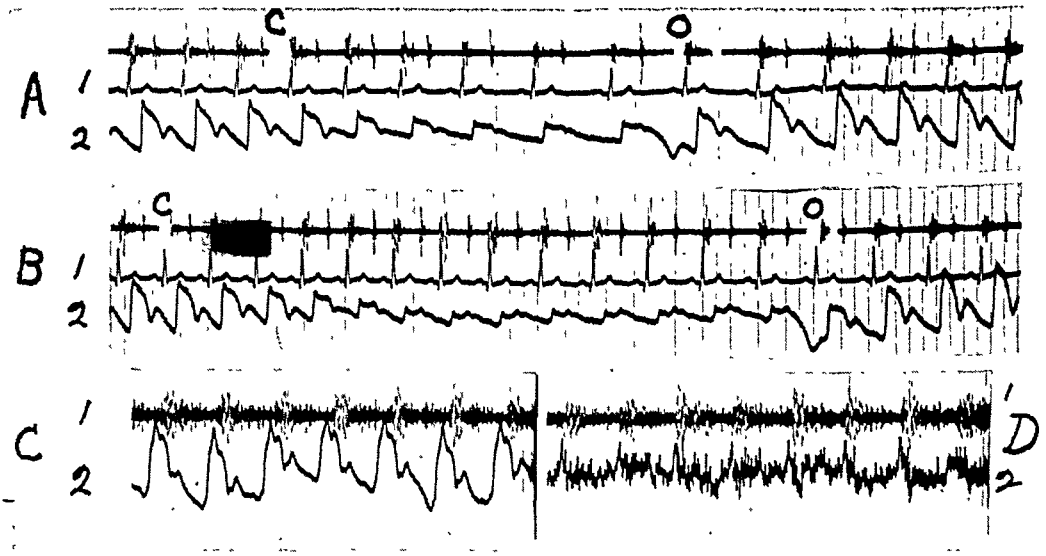



FIG. 5.—Case 1: (A) (1) Electrocardiogram, and (2) brachial pulse tracing with fistula closed at (C) and opened at (O). Brachial pulse shows prompt change in configuration on closing fistula due to increase in pressure. Retardation in pulse rate follows rise in pressure by several beats.

(B) Electrocardiogram and brachial pulse tracing following atropinization. On closing fistula brachial pulse shows prompt change in configuration due to rise in pressure but pulse is not retarded.

(C) (1) Sound-tracing of murmur at fistula showing systolic intensification. (2) Pulse-tracing of subclavian artery.

(D) (1) Sound-tracing of murmur at fistula. (2) Tracing of thrill over femoral vessels proximal to popliteal fistula.

which the fistula was closed during the first five seconds of the exposure and open during the second half of the exposure. (Fig. 7). Since the cardiac contraction rate was retarded when the fistula was closed, inspection of the kymogram enabled one to determine at a given second whether the fistula was open or closed by noting the contraction rate. A detailed study of the records obtained revealed the following variations in cardiac size depending upon conditions at the fistula (Fig. 8): Frame 1 recorded the right border of the right auricle. When the fistula was closed, the auricle was reduced in size, and when the fistula was opened the auricle was again distended.

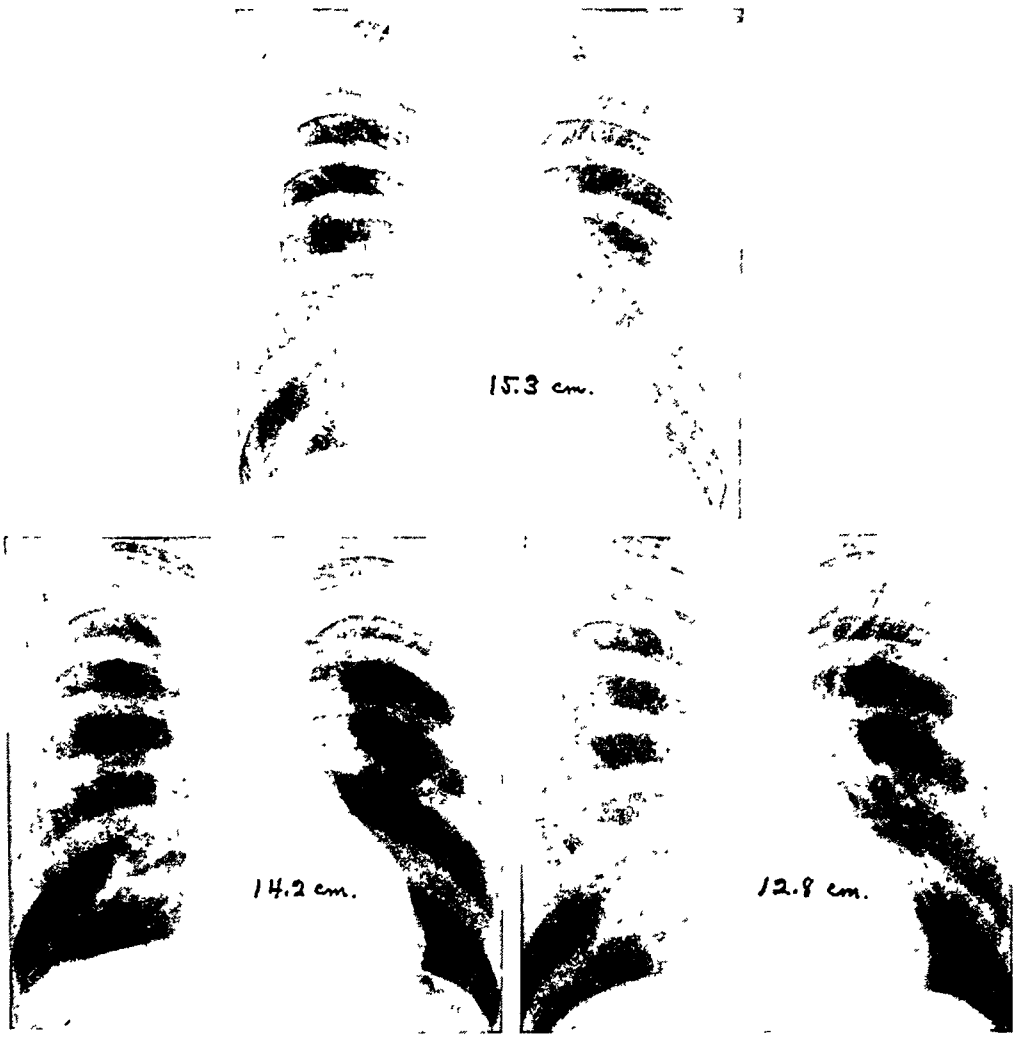



FIG. 6.—Teleroentgenograms in Case 1. (See text.)

Frame 2 recorded the left border of the descending aorta. When the fistula was closed the aorta was greatly distended, and when the fistula was opened, the aorta resumed its previous smaller size.

Frame 3 recorded the left border of the pulmonary conus. When the fistula was closed the pulmonary conus was reduced in size, and when the fistula was opened the pulmonary conus resumed its previously distended state.

Frame 4 recorded the left border of the left ventricle. When the fistula was closed the left ventricle was distended, and when the fistula was opened the ventricle decreased in size.

These variations in the size of the chambers and central vessels of the heart that follow immediately upon closing a fistula are explained as follows: Closing the fistula forces into the general arterial circulation including the

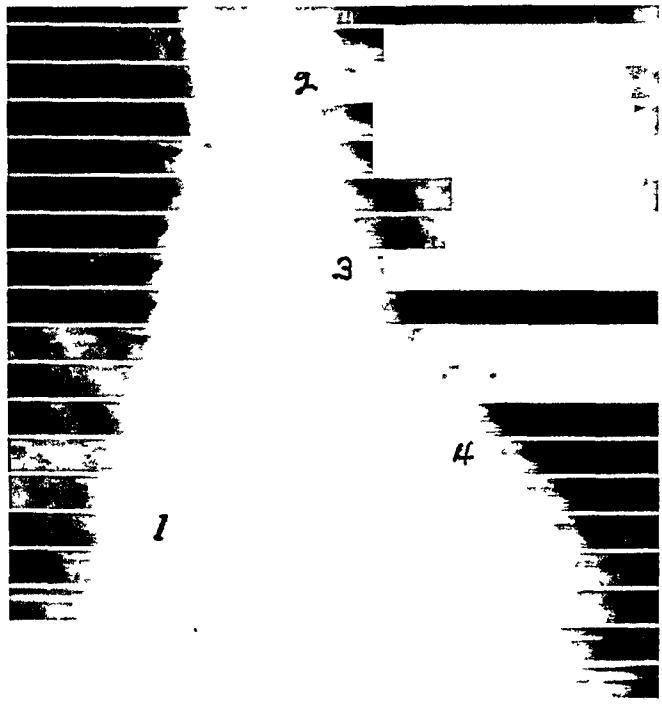



FIG. 7.—Case 1: Roentgenographic kymogram of heart in presence of popliteal fistula, which was closed by digital compression during first half of exposure and open during second half of exposure. (See Fig. 8.)

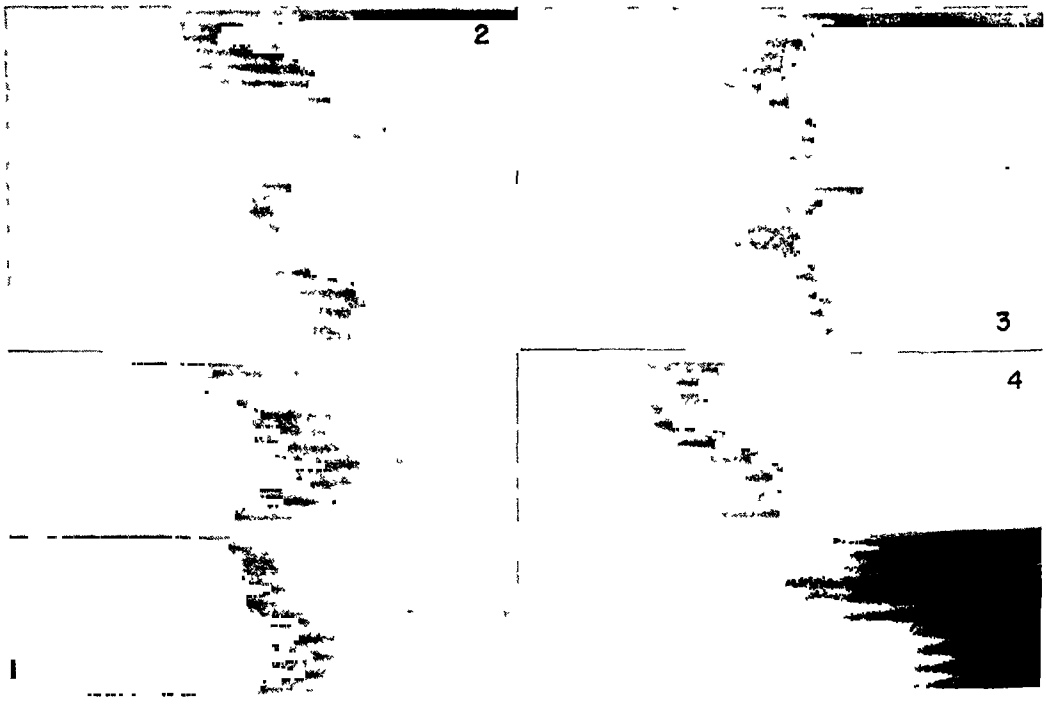



FIG. 8.—Enlargement of individual frames of roentgenographic kymogram shown in Figure 7. See text for explanation.

aorta and left heart the blood that formerly leaked through the fistula into the capacious venous system. But since the total blood volume has materially increased in the presence of the fistula its closure causes the entire arterial system to become distended with the abnormally increased blood volume which formerly coursed through the fistulous or parasitic circuit. This distention of the arterial system on closure of the fistula was disclosed by the kymographic enlargement of the aorta and left ventricle, and the reduced flow in the venous circulation was revealed in the decreased kymographic size of the right auricle and pulmonary conus.

In other cases following operation for *permanent* closure of the fistula,[26, 27] this overdistention of the already dilated heart and aorta was observed to be only temporary. The heart and the central vessels were seen to remain overdistended for approximately 24 to 36 hours. Since the need for the increased total blood volume was eliminated by the permanent closure of the fistula the total blood volume slowly diminished to normal, the volume or bulk of blood flowing through the heart was reduced to normal, resulting in an adjustment reduction also in the size of the heart itself to normal — except for a slight hypertrophy that had occurred during the life of the fistula. In numerous observations, the cardiac enlargement has been shown to be due mainly to a dilatation and to a lesser degree to hypertrophy. Even though cardiac output is greatly increased by a fistula, the stimulus to hypertrophy which this might provide is partly balanced or cancelled by the decreased cardiac effort incident to the decreased peripheral resistance and the lowered diastolic pressure imposed by the fistula.

The overdistention and then gradual reduction in cardiac size to normal following elimination of a fistula are exactly opposite to the changes that occur when a fistula is introduced into the circulation. Clinically, gradual dilatation to point of decompensation has been observed in a patient over a period of years[27] but more accurate studies of the effects of a fistula upon the heart have been made in the experimental laboratory.[27, 28] These demonstrate that the opening of a large fistula is accompanied by an immediate *decrease* in the size of the heart, due to the loss of blood from the arterial bed into the capacious venous system. This decrease, which is comparable with the reduction in cardiac size that accompanies serious external hemorrhage, is only fleeting, rarely lasting more than one or two days when the heart again returns to normal size, only to be followed by a gradual dilatation, as total blood volume is increased, and as the amount of blood flowing through the heart from the normal circulation is augmented by the volume of blood flowing through the fistulous or parasitic circuit. The rapidity of such dilatation is determined by the volume of blood short-circuited through the fistula which, in turn, is dependent upon several important variables: the size of the fistula, its location in the vascular tree, and its duration, all of which were originally stressed by Dienemann[29] as early as 1892. Much of the controversy with respect to a fistula emanates from failure to recognize the importance of these variables in producing

equally variable effects upon the circulation. Moreover, the character and type of healing that occur at the site of the fistula are also most important factors in determining the ultimate effects of a fistula upon the circulation. If fibrous tissue, rigid and inelastic, is deposited around the fistula, around the artery, or around the proximal vein, in sufficient quantity to prevent the subsequent dilatation of these structures, there will be marked limitation of the amount of blood short-circuited through the fistula and, therefore, the circulatory effects will be minimal or greatly limited. In fact, experimentally,[17] ligation of the vein proximal to a fistula completely prevented any subsequent dilatation of vessels or heart, and ligation of the artery proximal to the fistula resulted in dilatation of the artery *distal* to the fistula,[18] which is only a rare clinical observation.

The crucial factor in determining the amount of blood diverted through the fistula is the difference in peripheral resistances offered to the flow of blood in the normal circuit and in the fistulous or parasitic circuit. The nearer to the heart the fistula is located, the greater is the peripheral resistance distal to it, and also the greater is the difference between the high pressure in the artery and the absent or low pressure in the vein. This results in an easier flow of blood through the fistula than through the distal capillary bed and its high resistance. This tendency for blood to be diverted more readily through the fistulous circuit will continue so long as the resistance to its flow in this circuit is less than through the normal capillary bed. If the tissues at the site of the fistula are easily distensible, and if scar tissue is minimal, the equalization of resistances in the two circuits may be indefinitely postponed; *i.e.,* given the two possibilities of flowing through the fistula or through the capillary bed, blood will flow through the site of less resistance, which in the absence of unyielding scar tissue will be the easily distensible fistula. The increasing volume of blood flowing through the fistulous circuit because of its lessened peripheral resistance results in a gradual dilatation of all the component parts of the parasitic circulation. namely, the heart, the artery from heart to fistula, the fistula itself, and the vein from the fistula to the heart. Such a dilatation may be a very slow process, as illustrated by three clinical cases in which cardiac dilatation and decompensation took place 24, 25, and 26 years after the establishment of the fistula.[21, 26, 30] It also may occur very rapidly, as observed by Mason,[13] if the lesion is located in large vessels near to the heart.

If the fistula is small or if the scar tissue at site of the fistula is dense and unyielding, equalization of the resistances in the fistulous and normal circulations is reached soon, the volume of blood short-circuited through the fistula early reaches a stationary level, and dilatation of the fistulous circuit either will not occur or will be minimal. It is readily understood, therefore, how variable may be the effects of a fistula upon the circulation, depending in large measure upon conditions at the site of the fistula.

*Retardation in Pulse on Closing a Fistula.*—This highly interesting and unique phenomenon was first described in relation to an acquired

fistula by Branham,[22] but had previously been noted by Nicoladoni[1] in a congenital "phlebarteriectasie" of the right upper extremity, and by Israel[2] in a patient with congenital arteriovenous connections in the right lower leg. In each instance, occlusion of the proximal artery caused slowing of the pulse. Both Nicoladoni's and Israel's patients also exhibited greatly dilated hearts which in Israel's patient subsided to normal following amputation of the leg necessitated by gangrene which followed ligation of the femoral artery proximal to the abnormal communications.

Explanations for the occurrence of this retardation in pulse rate are few in number and in most instances are inadequate. That it is associated with the increased blood pressure that occurs on closing a fistula has been stressed by many writers. Weber[31] ascribed the increased blood pressure to the cardiac hypertrophy which he said occurred during the life of the fistula in order to maintain a normal blood pressure. On closing the fistula, the abnormally hypertrophied heart produced an abnormally increased pressure which, in turn, evoked a retardation in pulse through stimulation of the depressor nerve. He was probably the first to demonstrate that after atropinization the pulse did not slow, although the increase in blood pressure occurred as usual.

Von Bonin[32] asserted that the slowing of the pulse could not be consecutive to an increased blood pressure because the blood pressure was not always increased. He ascribed it to a chemical change, a diminution of oxygen content in the right auricle, acting upon the sinus control which during the presence of the fistula had become accustomed to an increased oxygen content of the blood.

Caro[33] thought the increased blood pressure on closing a fistula produced an increased intracranial pressure and, therefore, a stimulation of the vagus center. It is indeed a fact that every patient in whom the phenomenon of increased blood pressure and retardation of pulse is prominently exhibited, experiences a feeling of fullness of pressure in his head when the fistula is closed.

Lewis and Drury[9] explained the retardation as a vagal response to the increased blood pressure, but failed to explain the increased pressure. Indeed, few writers adequately explain the very unique but characteristic rise in pressure that follows closure of a fistula: the few beats of very high pressure followed by a drop to a lower level of increased pressure until the fistula is again opened (Fig. 3). This characteristic curve of blood pressure has been noted in numerous clinical cases and has been observed experimentally as well.[34] Examination of the pulse tracings and electrocardiogram in the present case corroborated a previous demonstration that the *first* effect of closing a fistula is the increased blood pressure and that the *second* effect is the retardation in pulse rate (Fig. 5). The present studies also corroborated previous observations[26] that atropine abolishes the retardation in pulse, but does not prevent the increase in blood pressure that occurs on closing a fistula.

The unequivocal enlargement of the aorta that occurs on closing a fistula as revealed in the present studies by the roentgenologic kymogram is highly important evidence in the explanation of this slowing of the pulse, which is invariable in the presence of a fistula large enough and of sufficient duration to produce a significant and demonstrable increase in total blood volume.[19] The slowing depends directly upon this increase in blood volume. When a fistula large enough to have produced such an increase in total blood volume is closed, the blood which formerly leaked into the vein is backed up into the arterial system, which then becomes overdistended and overfilled by the abnormally increased volume of blood. A demonstrable distention of the retinal arteries has been observed on closing a fistula[30] and now the roentgenologic kymograph has revealed a definite enlargement of the aorta on closing a fistula. The abnormal distention of the arch of the aorta in which reside the end-organs of the depressor nerve results in stimulation of these afferent vagal fibers, and an immediate slowing of the cardiac contraction rate occurs to neutralize or compensate for the excessive high blood pressure incident to overdistention of the arterial bed. The few beats of very high pressure occur before the pressure is reduced by slowing of the pulse, and before peripheral vasodilatation neutralizes part of the effect of the increased blood volume. Since blood volume cannot be immediately reduced to normal the increased pressure persists at a higher level as long as the fistula is closed depending upon the extent of the increase in blood volume. There can be no question of this intimate relationship of the retardation in pulse rate and of the increased blood pressure to the increase in total blood volume, which varies greatly depending on the variations in quantity of blood diverted through the fistula which, in turn, is determined by the variables already described.

Additional evidence supporting the importance of the increased blood volume is found in the behavior of blood pressure following permanent elimination of a fistula. The increase in systolic pressure which follows operation, (provided there is little loss of blood during the operation) soon subsides to normal as the increased blood volume is corrected. Concomitantly the retarded pulse rate again returns to normal. The permanently increased diastolic pressure following operative closure of fistula is attributed to the permanent elimination of the area of lessened peripheral resistance at the site of the fistula.

## SUMMARY

Roentgenologic kymography provides important observations on the effect upon the heart and large vessels of closing a large arteriovenous fistula. The immediate effect is shown to be additional distention of an already dilated heart and aorta. This distention is due to backing up into the arterial bed the volume of blood formerly flowing through the fistula into the capacious venous bed. Since a large fistula of long duration is invariably accompanied by an increased total blood volume the entire arterial bed

including the left heart and the aorta is overdistended by this increased blood volume when the leak into the venous bed is suddenly closed. The immediate effect of such an overdistention of the arterial tree is a marked elevation of general blood pressure, which is promptly though not completely rectified by a slowing of the cardiac contractions and by a retardation in pulse rate which is unique. Its mechanism is dependent upon stimulation of the fibers of the depressor nerve in the arch of the aorta by the overdistention of this vessel on closure of the fistula. It is eliminated by atropinization of the patient, indicating its vagal origin. It is dependent entirely upon the increase in total blood volume that occurs in the presence of a fistula of large size and long duration. If the closure of the fistula is permanent, as by operation, blood pressure and pulse return to normal through gradual reduction of blood volume to normal. That the increase in blood volume and resulting circulatory effects occur in all fistulae to greater or less degree seems likely, but they are not always demonstrable in small fistulae with small increases in blood volume by present instruments of precision or by present scientific methods. In small fistulae also, these changes may be masked by other physiologic adjustments such as peripheral vasodilatation which may obviate the increase in general blood pressure when the blood volume increase is small.

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DISCUSSION.—DR. DANIEL C. ELKIN, Emory University, Ga.: There has been considerable controvery for a number of years about the question of blood volume in the presence of an arteriovenous fistula. At the Ashford General Hospital we made observations on the blood volume in 40 patients with this condition. The plasma volume was determined by the use of the blue dye T–1824. The total blood volume was calculated from the plasma volume and hematocrit reading. Following removal of the fistula almost one-half of the patients showed a significant decrease in blood volume, some as much as 1,000 cc. per square meter of body surface. In general,

the greatest increases in blood volume were observed in patients who had fistulae in the larger vessels, such as the femoral and iliac. All this merely confirms what Doctor Holman has claimed for many years.

DR. RUDOLPH MATAS, New Orleans, La.: All workers in the surgery of arteriovenous aneurysms are Doctor Holman's debtors for his fundamental researches in this field. In this very valuable paper he has fully confirmed his original interpretation of the dilation of the heart and aorta, following the establishment of an arteriovenous communication and the Nicoladoni-Branham bradycardiac syndrome, with restoration to normal that follows its closure.

DR. EMILE HOLMAN, San Francisco, Calif. (closing): It may well be asked why dilatation and the bradycardiac reaction do not occur in all fistulae. They depend on the amount of blood flowing through the fistula, and we believe this is determined by the gradual dilatation of the fistula over a period of years. We found that in this instance the fistula had a diameter of 2 to 2.5 cm., whereas the original artery was no larger than 8 mm. The fistula dilated as the shorter circuit increased in size. Certain fistulae, however, do not dilate because of fibrous tissue deposited around the fistula which prevents its dilatation. Dilatation of the fistula, therefore, does not occur in all instances, depending upon the amount of scarring at the site of the fistula, and as a result of progressive dilatation of the heart also, does not occur in all instances.

## BOOK REVIEW

SURGICAL TREATMENT OF THE NERVOUS SYSTEM. By F. W. Bancroft and C. Pilcher. J. B. Lippincott Company, Philadelphia, Pa. 1946.

PILCHER has done neurosurgery a distinct service by collecting together in a single book definitive articles by recognized authorities on all the many angles involved in modern neurosurgery. Those of us who are old enough can remember when a neurosurgeon concerned himself only with brain and spinal cord tumors, trifacial neuralgia and focal epilepsy. Now the surgery of the sympathetic nervous system, of ruptured intervertebral disks, of athetosis and dystonia, and of hydrocephalus are included. Of particular value and importance is the emphasis placed upon peripheral nerve injuries by devoting an entire section to this subject which was well nigh forgotten between wars.

A new group of neurosurgeons is coming forward, some of them trained only in the care of battle casualties. To these men in particular this well-rounded reference book to all facets of their specialty will be of value. And to any neurosurgeon, young or experienced, this volume will be a source of valuable information. The older men may not agree with all they find here, but in agreement or not, they must admit that the methods outlined are sound and set forth by authors of wide experience. An important chapter bringing up to date the most recent advances in chemotherapy and its value in neurosurgery is included.

The print is good, the bibliographies adequate and typographic errors few and far between. The illustrations are the only unfortunate part of this book. Some of them, especially those in the chapters dealing with the sympathetic nervous system, peripheral nerves and the spinal cord are as fine as any we have ever seen. But others, particularly artists' sketches of the various intracranial lesions are simply very bad.

This is a highly satisfactory book which it was a pleasure to review. Every younger neurosurgeon should make an effort to include it in his library. A careful study of its contents will be very rewarding.

FRANCIS C. GRANT, M. D.

# ARTERIOVENOUS ANEURYSM OF THE VERTEBRAL VESSELS*

## REPORT OF TEN CASES

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THE MANY VASCULAR INJURIES resulting from wounds received in the recent war have given rise to an unprecedented number of arteriovenous fistulae and aneurysms. At the Ashford General Hospital approximately 500 operations have been performed for these conditions. Ten of these were arteriovenous fistulae of the vertebral vessels in their cervical or extracranial course. It is the purpose of this communication to report these cases and in so doing to review the anatomy of the vessels, the diagnosis of the lesion, and to suggest operative methods of approach and treatment based on this experience.

Reports of arteriovenous aneurysms of the extracranial portion of the vertebral vessels are rare, and have in most instances been concerned with the recording of an experience in the treatment of one case. However, Matas,[1] in 1893, collected 19 cases from the literature and included one of his own. In addition, Perrig[2] collected 60 instances of vertebral aneurysms, but in some of these the diagnosis was open to question. Recently, Heifetz,[3] in reporting a case of his own, collected the literature on this subject, and from his excellent review it would appear that somewhat less than 100 instances have appeared in literature. Moreover, in these reports the differentiation between arteriovenous fistulae and false arterial aneurysms is not clearly brought out. Undoubtedly this number does not represent the true incidence of the condition, since single cases, particularly if ending fatally, are not so apt to be reported. At any rate, it remains among the rarest of arterial injuries, probably because of the anatomic location of the vessels.

The mortality in previous reports, either as a direct consequence of the lesion or its treatment, appears to be above 50 per cent, far higher than that of aneurysms or arteriovenous fistulae in any other location. Here, again, the anatomic position of the vessels is undoubtedly a contributing factor because of the difficulties attendant upon the operation.

### ANATOMY

The extracranial portion of the vertebral artery lies deep in the neck. For descriptive purposes it is divided into three parts: The *first portion* which runs from its origin in the subclavian artery to the foramen in the

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

transverse process of the sixth cervical vertebra; the *second portion* which runs through the foramina in the transverse processes of the upper six cervical vertebrae; and, the *third portion* which consists of that part of the vessel from its exit from the foramen in the atlas until it enters the skull through the foramen magnum (Fig. 1).

It is important to remember that the vertebral artery is the *first branch* given off by the subclavian artery. It springs from the upper posterior

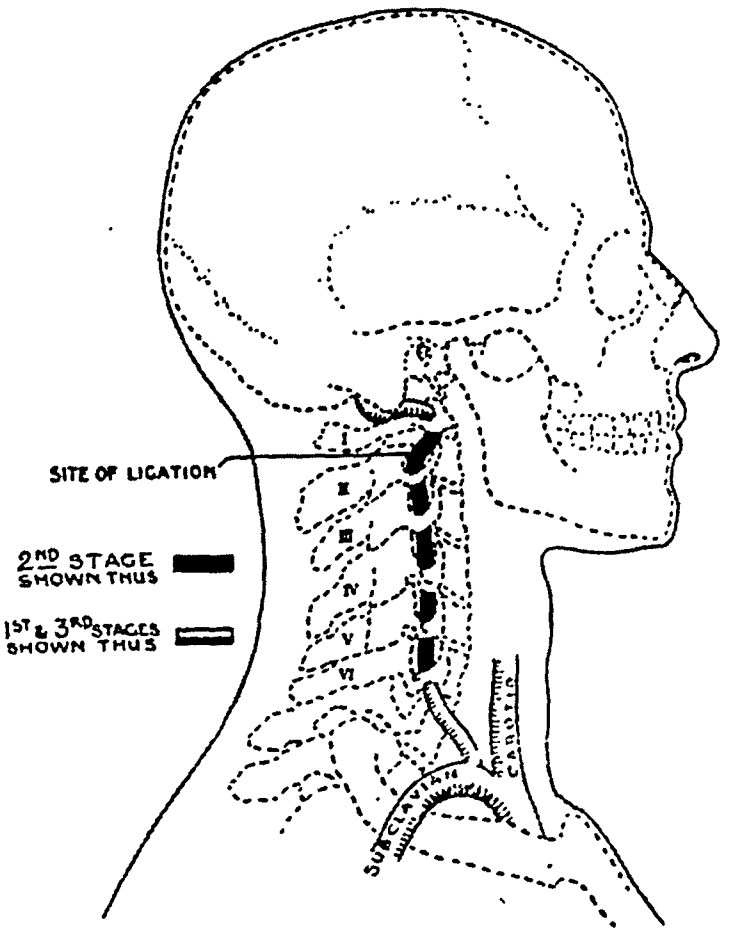



FIG. 1.—Diagrammatic representation of the first, second and third portions of the vertebral artery. The second portion is shown in black. (From Henry).

aspect of the first portion of that vessel just lateral and posterior to the common carotid artery and about .5 cm. from the medial margin of the anterior scalene muscle. This muscle is a guide to the artery. The thyrocervical trunk arises from the upper portion of the subclavian just distal to the vertebral, and because of their close approximation they may be mistaken for each other unless careful dissection is employed.

The *first part* runs upward and backward between the longus colli and anterior scalene muscles. Behind it is the transverse process of the seventh cervical vertebra and the sympathetic chain. In front of it is the vagus nerve, the internal jugular vein, and in front of this vein, the sternomastoid muscle. The upper portion of this part is crossed by the inferior thyroid

artery as it passes medially. The vessel *does not* enter the foramen in the transverse process of the seventh cervical vertebrae, but as previously stated, lies in front of it.

As the *second part* passes upward through the transverse processes of the upper six cervical vertebrae it lies anterior to the cervical nerves and beneath the anterior scalene muscle. In this portion it is surrounded by a venous plexus which terminates below in the vertebral vein. Overlying the vessel and slightly to its medial side is the internal jugular vein and more superficially the sternomastoid muscle. In the upper part of the second portion the spinal accessory nerve is found about two fingerbreadths below the mastoid process. Deep to the sternomastoid muscle the dense prevertebral fascia covers the levator scapulae muscle. This muscle arises from the transverse processes of the upper four cervical vertebrae and, therefore, directly overlies the vertebral vessels in their course through the upper four foramina.

The *third part* begins at the point where the vessel emerges from the foramen of the atlas. It turns backward and lies in a groove on the upper surface of that bone. Here the vessel is covered by the semispinalis capitis in the suboccipital triangle. The guide to the upper portion of the vessel is the transverse process of the atlas which can easily be palpated one fingerbreadth below and one in front of the tip of the mastoid bone. It is more easily identified when the sternomastoid muscle is detached from its origin, as will be discussed below.

## DIAGNOSIS

Of all the aneurysms and fistulae in the body the diagnosis of those of the vertebral vessels is the most difficult to make. It was made with certainty in only five patients in this series, although it was suspected in others. It is likely to be confused with more common lesions in this region, particularly fistulae between the internal jugular vein and branches of the external carotid artery. It may also be confused with fistulae arising from other branches of the subclavian artery, particularly the inferior thyroid, the transverse scapular and transverse cervical vessels. Since the common carotid lies moderately superficial in the neck where it can be occluded by digital pressure, the bruit of fistulae arising from branches of this vessel are usually obliterated with ease. *If the bruit does not disappear on compression of the common carotid artery the vertebral vessels should be suspected as the site of the lesion.* Since the vertebral vessels lie deep in the neck, obliteration of the bruit is difficult to obtain by pressure.

## OPERATION

The approach to any portion of the vertebral vessels is a difficult one because of its deep position and because of the vital nature of its surrounding structures. Since the anatomy of the three parts varies greatly, the approach to the vessels in these regions will be considered separately.

In the first portion it can best be reached through an incision parallel

to the fibers of the sternomastoid muscle and directly over the interval between the sternal and clavicular heads of that muscle. After the deep fascia is incised, the two heads of the muscle are separated and retracted (Fig. 2). If necessary to obtain better exposure no harm is done by transversely dividing some of the fibers of this muscle. When the internal jugular vein is

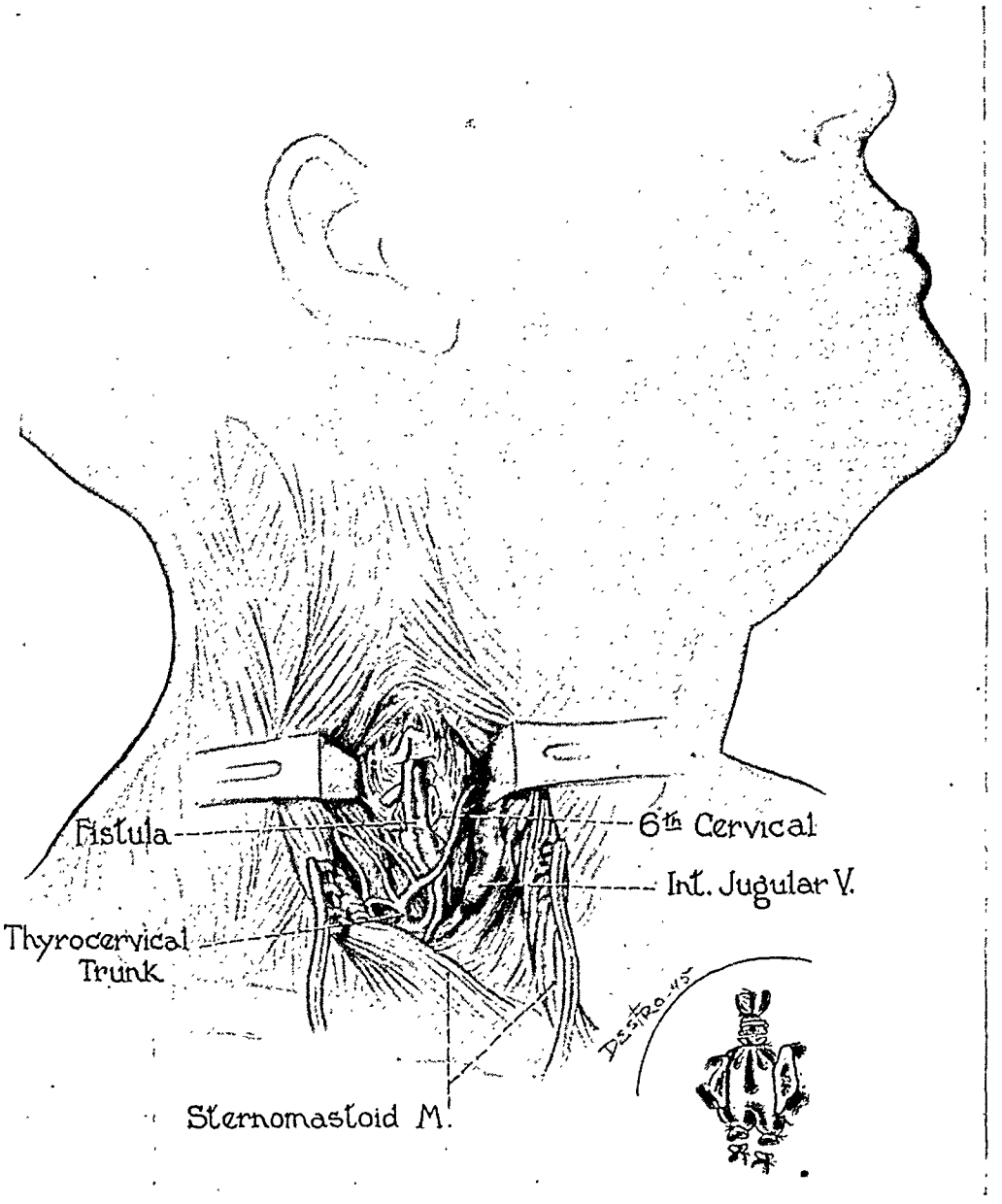



FIG. 2.—The approach to the first portion and the lower part of the second portion of the vertebral vessels.

encountered in the depth of the incision it is retracted medially and the triangular interval between the longus colli and the anterior scalene muscles is developed. The inferior thyroid artery will be found running upward and medially and crossing in front of the vertebral artery in this region, and the two must be carefully isolated. On the left the thoracic duct passes in front of the artery. The vertebral artery arises medial to the inferior thyroid and in this location can be identified by its pulsation. The vertebral

vein lies anterior to the artery. This portion of the vertebral artery should always be identified as a preliminary step in operations on the vessel elsewhere in its course. A ligature passed around the vessel, but not tied, serves as a protection should hemorrhage occur later in the operation. It should be remembered, however, that there is a rich anastomotic blood supply in the vertebral system, and that ligation of the proximal artery will only diminish and not control hemorrhage. Ligation at this point in the operation should



FIG. 3.—The incision for exposure of the third portion of the vertebral vessels.

not be done since it will obliterate the thrill and bruit, thus, making identification of the fistula more difficult.

The second portion of the vessel is reached by an incision along the anterior border of the sternomastoid muscle. When the deep fascia is opened the muscle is retracted laterally and the carotid sheath identified and retracted medially. It is usually necessary to divide the omohyoid muscle as it passes across the carotid sheath. The anterior scalene muscle which arises from the transverse processes of the third, fourth, fifth, and sixth

cervical vertebrae is retracted laterally and, if necessary, may be detached from its origin to fully expose the transverse processes through which the vertebral vessels pass. The interval between the transverse processes is less than a fingerbreadth, and ligation in this region is particularly difficult unless one or more of the transverse processes is removed by rongeur. When this is done a ligature may be passed, preferably on an aneurysm needle, about the vessel or it may be occluded by the use of heavy metal clips.

Exposure of the upper portion of the second part and of the third part of the vertebral vessels is by far the most difficult. Henry[4] has described a

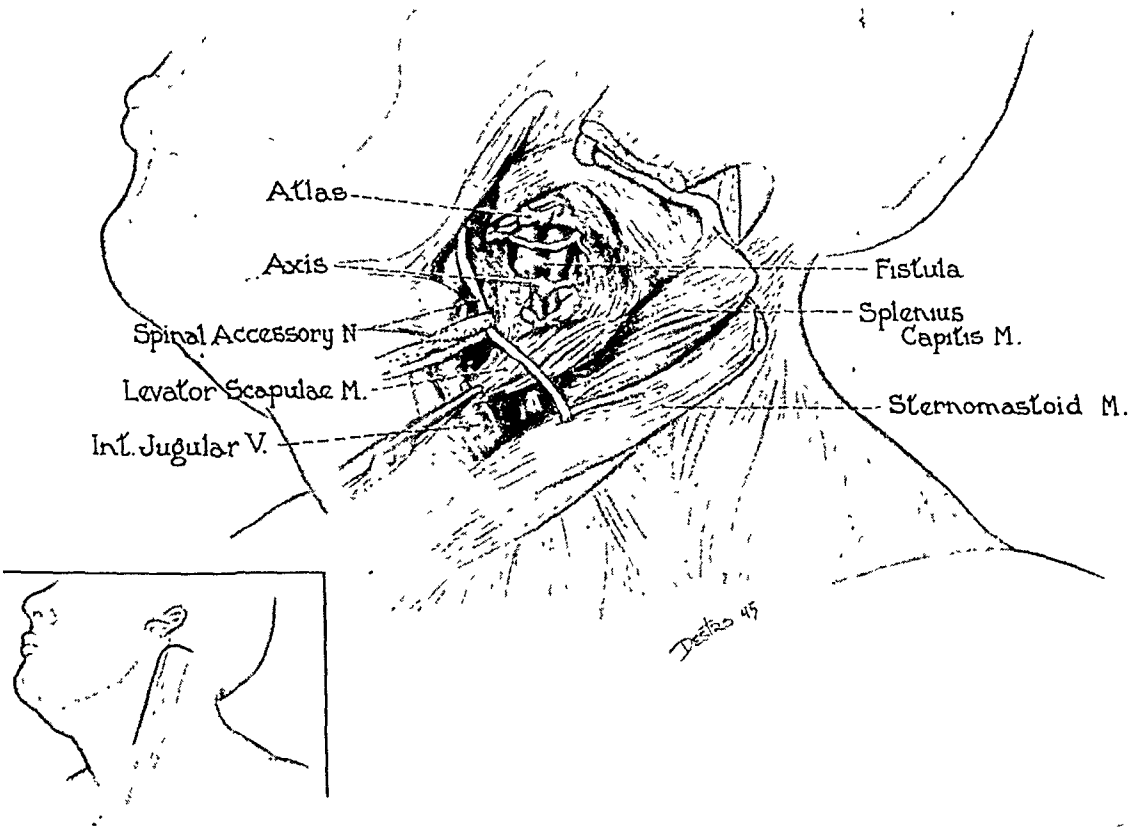



FIG. 4.—The exposure of the upper portion of the vertebral vessels.

method of approach for the purpose of ligating this portion of the vessel which we have successfully employed in four instances (Cases 3, 6, 9 and 10). The patient lies on his back with the neck extended and the chin turned to the side opposite the involved vessels. An incision is made along the anterior border of the sternomastoid muscle from the middle of the neck to the mastoid process (Fig. 3). The deep fascia is opened and the insertion of the sternomastoid is cut away from the bone and the muscle reflected laterally. The spinal accessory nerve is isolated and mobilized as it passes laterally and downward beneath the sternomastoid muscle (Fig. 4). With the reflection of the muscle the tip of the transverse process of the atlas is easily identified. The prevertebral fascia is divided from above downward

and the origin of the levator scapulae muscle is cut away from the atlas and axis and turned downward. Further dissection will expose the vertebral artery and surrounding venous plexus in the interval between the atlas and axis, as well as in its third portion.

The fistula in all the cases of this series was produced by trauma. In nine patients it was due to direct injury of the vessels by a missile, usually a small fragment of high explosive shell. In one instance (Case 6), there was no penetrating wound and the fistula followed severe external trauma caused by a blow from a piece of wood. In none was there a fracture of the transverse process of the vertebra discernible by roentgenogram, but this type of injury should be borne in mind as a possible cause of the condition.

In the ten cases here reported the lesion was located in the first portion of the vessel in one instance, in the second portion in six instances, and in the third portion in three instances. In none was any attempt made to repair the fistula. The position of the vessels as well as their small size will preclude any effort of repair. Its anatomic position prevented actual excision of the fistula except in three instances (Cases 1, 2 and 8), and, therefore, its obliteration was usually accomplished by proximal and distal ligation of the vessels and the placing of mass ligatures. It is to be stressed that complete control of the blood supply is necessary for the prevention of hemorrhage. One should not hesitate to remove the transverse processes of the cervical vertebrae in order to completely expose the lesion and its contributing vessels.

## REPORT OF CASES

CASE 1.—*A-V fistula, left vertebral vessels, upper third, due to bullet wound November 10, 1942. Excision of fistula through suboccipital approach, June 15, 1943. Secondary hemorrhage controlled by ligation of the vertebral artery and packing wound. Cured.*

On November 10, 1942, this soldier was struck in the left malar region with a 44-caliber bullet. The missile traversed the face, the lateral aspect of the neck, and became imbedded in the soft tissues of the left occipitomastoid region. There was no extensive external hemorrhage, but the tissues of the left side of the neck swelled considerably. Within a few days he noticed a loud buzzing in his left ear. Upon occasion his pulse rate would become rapid. On December 22, 1942, the bullet was removed, and on February 22, 1943, the left common carotid artery was ligated without change in his symptoms.

On admission to the Ashford General Hospital, two months later, there was a small scar over the left malar region; the wound of entry. There was an operative scar 4 cm. mesial to the tip of the left mastoid. The tissues in this region appeared full in comparison to those on the right. Palpation revealed a deeply situated pulsating mass with a distinct systolic thrill. On auscultation, a continuous bruit accentuated in systole with maximal intensity over the occiput could be heard. This could be obliterated by deep pressure over the sternomastoid muscle. Arterial pulsation was absent over the left common carotid artery, the site of the earlier ligation. It was thought that this was an arteriovenous fistula of the cirsoid type, probably involving the occipital artery and vein deep to the muscles and posterior to the mastoid process. The question of involvement of the vertebral artery with accompanying veins in this region was considered.

An excision of these vessels was carried out June 15, 1943. A semicircular incision beginning over the left mastoid muscle was carried upward over the base of the skull to the midline. The deep muscles were cut and retracted caudally. The external carotid artery was ligated; however, this had no effect upon the aneurysm which could be seen and felt at the base of the skull. The aneurysm was excised by ligating and cutting numerous arteries and veins which could be seen to communicate with vessels entering the skull. Considerable bleeding was encountered which was controlled by coagulation and by the use of fine silk ligatures. At the end of the operation the bruit and thrill had disappeared.

Two weeks later, as a result of a friendly wrestling match, the wound was opened and severe secondary hemorrhage occurred. This was controlled by hemostats, which were left in place, and by packing. Following this the vertebral artery was ligated in its first portion, which apparently controlled the bleeding since no further hemorrhage occurred with removal of the clamps and packing five days later. The wound healed uneventfully. There was no return of the bruit and thrill upon discharge three months later and upon review examination three months after discharge.

CASE 2.—*A-V fistula, left vertebral vessels, upper third, due to shell fragment wound September 14, 1943. Ligation of left vertebral artery January 20, 1944, with improvement. Partial excision of fistula February 2, 1944. Complete excision April 20, 1944. Cured.*

On September 14, 1943, this soldier was struck in the left side of the face by a fragment of high explosive shell. The wound of entrance was just anterior to the left ear and there was no wound of exit. He was unconscious for approximately three hours after the injury. There was considerable bleeding from the wound. On regaining consciousness he noticed impairment of hearing on the left with numbness and weakness of the left side of the face. On the following day he developed an occipital headache and diplopia which persisted for nine days. The left side of the face became markedly swollen. On admission to the Ashford General Hospital, four months later, there was a paralysis of the left side of the face, impairment of hearing of the left ear with narrowing of the left external auditory canal and the left ear drum completely replaced by granulation tissue. A continuous bruit and thrill were present over the left side of the face and neck, with maximum intensity in the occipital region. An expansile pulsation was noted in this region. A metallic foreign body was present at the tip of the spinous process of C-1 on the left. A diagnosis of arteriovenous fistula of the vertebral vessels was made.

On January 20, 1944, the external carotid artery and the first portion of the vertebral artery on the left were ligated. There was a definite decrease in the bruit when the vertebral artery was ligated. On February 2, 1944, an attempt was made to excise the arteriovenous fistula. A 10-cm. longitudinal incision was made from the skull downward along the posterior border of the sternomastoid muscle. After opening the deep fascia a large plexus of arteries and veins, in which a thrill could be felt, was disclosed. The veins were dilated and friable, and they, together with a mass of arteries, were individually isolated, ligated, and removed. It was felt that further extension of the aneurysm might be present in the deeper structures, but continuation of the procedure at that time was not justified as it was hoped that a cure had been accomplished from this procedure. Following operation the bruit was markedly diminished but was still audible. On April 13, 1944, the right vertebral artery was ligated. On April 20, 1944, an incision was made through the old scar along the posterior border of the sternomastoid muscle. Deep in the wound a pulsating mass could be felt which was in the vertebral vessels between their exit from the transverse process of the first cervical vertebra and their entrance into the skull through the foramen magnum. This position made the approach extremely difficult since there was no means of isolating the blood vessels. However, the mass was exposed, the vertebral vessels at the base of the skull were clamped, and the fistula was excised. The vessels were ligated with silk

with considerable difficulty and one vessel which split to the foramen magnum was sutured after the hemorrhage was controlled by finger pressure. This was done by passing three silk ligatures under the finger. When the mass was removed no further bruit or thrill was heard or felt. The postoperative course was uneventful. There was no recurrence of the bruit or thrill at the time of discharge two months later.

CASE 3.—*A-V fistula, left vertebral vessels, second portion, due to shell fragment wounds June 28, 1944. Ligation of vertebral artery in the first portion, December 30, 1944, with improvement. Ligation of the vertebral artery between atlas and axis, February 3, 1945, with further improvement. Removal of transverse processes of third and fourth cervical vertebrae and mass ligation of fistula, April 25, 1945. Cured.*



FIG. 5.—Case 3: Silver clip on the upper portion of the vertebral artery.

On June 28, 1944, this soldier was struck in the right arm and neck by multiple fragments of an artillery shell. There was profuse bleeding from all wounds. The neck wound was débrided and healed promptly. Approximately three weeks later he noted a buzzing sensation in the left side of the neck but did not hear any noise. He reported this to his medical officer who made a diagnosis of arteriovenous fistula. On admission to the Ashford General Hospital, five months later, there was a small scar overlying the upper portion of the left sternomastoid muscle about 4 cm. below the angle of the mandible. There was a continuous bruit and thrill heard and felt over this area, which

were transmitted up the scalp to the parietal region and into the neck to the clavicle. Deep pressure failed to obliterate the bruit and thrill. It was thought that this was an arteriovenous fistula of the second portion of the left vertebral vessels. On December 30, 1944, the first portion of the vertebral artery was ligated and divided. This caused the thrill and bruit to be almost completely obliterated. On February 3, 1945, an incision was made from the level of the thyroid cartilage upward along the anterior border of the sternomastoid muscle to the mastoid process and then turned backward severing the sternomastoid from the skull at its insertion. The muscle was retracted laterally and the third cervical nerve and the spinal accessory nerve were isolated. The levator scapulae muscle was detached from its origin from the atlas, axis, and third and fourth cervical vertebrae. The vertebral vessels were then isolated between the transverse processes of the atlas and axis. The sensory branch of the second cervical nerve overlying the vessels was dissected free and the vertebral artery was divided between ligatures. Several smaller vessels in this region were also ligated. The vein was not ligated. This stopped the thrill but a bruit was still present.

The bruit increased in intensity and, April 25, 1945, the scar on the left side of the neck was excised and the sternomastoid muscle retracted laterally. The transverse processes of the first, second, third, and fourth vertebrae were exposed. The levator scapulae muscle was detached from the transverse process of the atlas and the spinalis group of muscles freed from the transverse processes of the above vertebrae by sharp and blunt dissection. The lateral roofs of the foramina transversarium of the third and fourth cervical vertebrae were removed by rongeur. This exposed the vertebral vessels for a distance of 4 or 5 cm. The fistula was apparently at the level of the inferior border of the canal of the third vertebra. Ligatures were passed about the vessels proximal and distal to the fistula and the vessels ligated. Silver clips were applied above and below the fistula (Fig. 5). This caused the bruit and thrill to completely disappear. There was no recurrence of the bruit or thrill at the time of discharge three months later.

CASE 4.—*A-V fistula, right vertebral vessels, second portion, due to rifle bullet wound September 15, 1944. Removal of transverse process of sixth cervical vertebra. Mass ligation of vertebral vessels, January 16, 1945. Cured.*

On September 15, 1944, this soldier was struck in the right side of his neck by a rifle bullet. The wound of exit was in the anterior aspect of the left infraclavicular region. There was profuse bleeding from the right side of the neck, which was controlled by pressure. On September 17, 1944, the wound of the left shoulder region was débrided and a plaster splint applied because of a fracture of the left clavicle. Several weeks later a pulsating mass in the right side of the neck was discovered. The wound on the right healed without difficulty. On admission to the Ashford General Hospital, five weeks later, there was a healed wound, about 3 cm. in length, on the right side just above the clavicle. There was also a granulating wound in the left infraclavicular region. There was a continuous bruit and thrill in the anterior triangle of the right side of the neck, which was transmitted along the course of the carotid vessels and was audible in the chest. Upon obliteration of the fistula the pulse fell from 84 to 76 and the blood pressure in the right brachial artery rose from 160/90 to 160/110. It was thought that this was an arteriovenous fistula of the right common carotid artery and internal jugular vein. On January 16, 1945, a longitudinal incision was made on the right from the clavicle to the level of the thyroid cartilage. The incision was extended between the two heads of the sternomastoid muscle and the common carotid artery and internal jugular vein were isolated. There was no evidence of a fistula present in this region and as pressure beneath the clavicle caused the bruit and thrill to disappear it was felt that the fistula was at a more proximal point. The lower end of the incision was then extended laterally over the clavicle and the proximal third of this bone resected subperiosteally. Isolation of the common carotid artery to the innominate revealed no evidence of a fistula. It was then discovered that the fistula involved the

vertebral vessels at a point near the bony canal of the sixth cervical vertebra. The carotid artery and internal jugular vein were retracted medially and the vertebral vessels isolated to the point where they passed into the foramen transversarium of the sixth cervical vertebra. Occlusion of the artery at this point caused the thrill to disappear but the bruit was still audible. The lateral roof of the foramen transversarium of the sixth cervical vertebra was removed by rongeur, and occlusion of the vessels just proximal to the fifth cervical vertebra did not cause the thrill to disappear. The artery and vein proximal to the fistula were doubly ligated, transfixed and divided. Ligatures were passed about the vessels distal to the fistula in the space between the



FIG. 6.—Case 5: Swelling of the neck produced by false sac of vertebral arteriovenous aneurysm.

fifth and sixth vertebrae and the vessels doubly ligated. There was moderate hemorrhage from the venous plexus extending into the spinal canal, which was controlled by pressure and muscle packing. The bruit and thrill completely disappeared. The wound healed without difficulty. The bruit and thrill had not recurred at the time of discharge four months later.

CASE 5.—*A-V fistula, with false sac, right vertebral vessels, second portion, due to shell fragment wounds January 14, 1945. Ligation of vertebral artery in first portion, and intrasaccular closure of fistula with sutures and silver clips, March 13, 1945. Cured.*

On January 14, 1945, this soldier was struck in the right shoulder, neck, and the left side of back by multiple fragments of a high explosive shell. There was no loss of consciousness and he was able to walk about after injury. About two weeks later he noted a swelling in the lower posterior aspect of the right side of his neck. Ex-

amination revealed the presence of a continuous bruit and a pulsating mass in this region. On admission to the Ashford General Hospital two months later there was a fusiform, firm swelling in the posterior aspect of the right side of the neck (Fig. 6). No thrill could be felt in this region, but a continuous bruit was heard along the anterior and posterior borders of the mass. The bruit could not be obliterated by occlusion of the common carotid artery low in the neck. It was thought that this was an arteriovenous fistula, with false sac, possibly involving the transverse cervical or the vertebral vessels.

On March 13, 1945, a preliminary incision was made just above the clavicle and the clavicular portion of the sternomastoid muscle divided. The transverse cervical

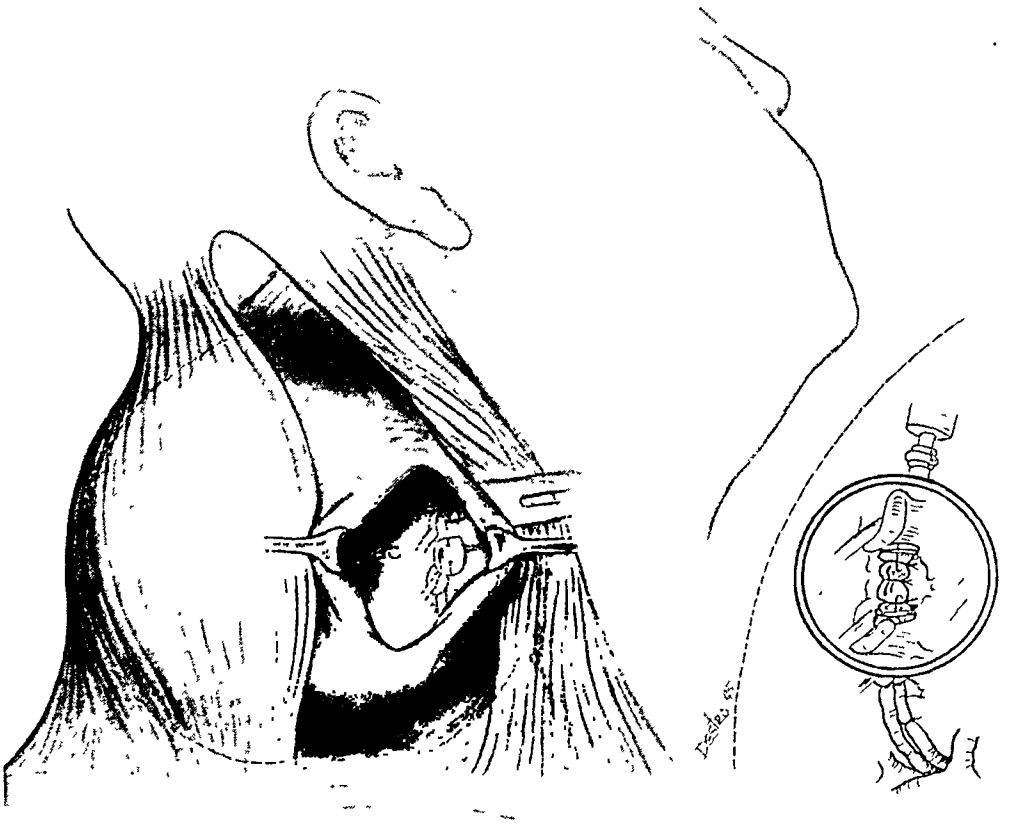


FIG. 7.—Case 5: Exposure of the vertebral vessels by incision through the false sac. Insert shows obliteration of the fistula by clips and mass ligatures.

artery was ligated, which had no effect upon the bruit. The anterior scalene muscle was divided, exposing the subclavian artery. Occlusion of the vertebral artery caused the bruit to disappear. A "bulldog" clamp was applied to the vertebral artery and another clamp applied to the subclavian, hoping that some anastomotic circulation would be retarded. Another incision was then made longitudinally in the posterior triangle of the neck anterior to the trapezius muscle. The spinal accessory nerve was exposed and retracted from the wound. The sac was opened and a large clot, perhaps 500 cc., was evacuated. Two openings into this sac were found to come from the vertebral artery at the interval between the fourth and fifth processes of the cervical vertebrae. Four sutures of silk and three silver clips were placed on the vessel which stopped all the bleeding. The vertebral vein was probably included in these ligatures and clips. The vertebral artery was then ligated but not divided at the point where it was previously dissected near its origin from the subclavian artery. (Fig. 7) The wounds healed without difficulty. There was no recurrence of the bruit at the time of discharge four months later.

CASE 6.—*A-V fistula, left vertebral vessels, second portion, due to injury from falling log February 13, 1945. Removal of transverse process of second cervical vertebra. Multiple ligation of vessels and application of silver clips at point of fistula, May 24, 1945. Cured.*

On February 13, 1945, this soldier was struck on the left side of the face and neck by a falling log. There was no evidence of a penetrating wound. The patient was unconscious for about 30 minutes. There was marked swelling of the left side of the neck for ten days. Severe headaches of the left parietal region were present for two weeks, with stiffness of the neck and tenderness along the cervical vertebrae. Following the injury a roaring sensation developed in the left ear which was accentuated by each heart beat. About a month after injury the presence of a continuous bruit was noted in the upper posterior portion of the left neck inferior to the mastoid. On admission to the Ashford General Hospital, three months later, there was no evidence of an external wound, but a continuous bruit and thrill were present in the left side of the neck just below the mastoid. Occlusion of the common carotid artery did not cause the bruit to disappear. It was thought that this was an arteriovenous fistula of the second portion of the vertebral vessels.

On May 24, 1945, a longitudinal incision was made on the left side of the neck extending from the mastoid process to the level of the thyroid cartilage. The sternomastoid muscle was retracted laterally and the carotid vessels medially. The transverse processes of the first, second, and third cervical vertebrae were exposed by detaching the levator scapulae muscles from the transverse processes of the atlas and axis, and detaching the spinalis muscles from the transverse processes of the first, second, and third cervical vertebrae by sharp and blunt dissection. The fistula was apparently at the level of the inferior border of the vertebral canal of the second cervical vertebra. The roof of the foramen transversarium of the second cervical vertebra was removed by rongeur. This allowed exposure of approximately 2.5 cm. of the vertebral vessels. Ligatures of silk were passed about the vessels proximal and distal to the fistula and the vessels doubly ligated above and below the fistula. This caused the bruit to diminish but not disappear. The collateral vessels were ligated in a similar manner which caused the bruit and thrill to completely disappear. Silver clips were applied to the vessels proximal and distal to the fistula. The wound healed without difficulty. Although the patient developed Horner's syndrome following the operative procedure, there was no evidence of injury to the posterior root of the second cervical nerve. The bruit and thrill had not recurred at time of discharge three months later.

CASE 7.—*A-V fistula, right vertebral vessels, second portion, due to shell fragment wounds February 20, 1945. Quadruple ligation of vessels, July 27, 1945. Cured.*

On February 20, 1945, this soldier received high explosive shell fragment wounds of the right side of the neck, shoulder, arm, and chest wall. The wound of the neck bled profusely and was controlled by a pressure bandage. The right upper extremity was paralyzed at the time of injury but there was returning function at the time of admission to the Ashford General Hospital. The wounds of the neck were not débrided. Within 24 hours after admission to an Evacuation Hospital, the presence of a bruit and thrill were discovered in the right side of the neck. Examination at the time of admission to the Ashford General Hospital, June 11, 1945, revealed a small scar in the right lower neck. A definite thrill was felt and a continuous bruit heard in this region. The bruit was transmitted up the course of the carotid vessels and also along the axillary vessels. The bruit and thrill could not be completely obliterated by pressure. Almost complete obliteration caused the pulse to drop from 92 to 84 and the blood pressure to change from 110/70 to 110/80. There was partial brachial plexus paralysis with atrophy of the right hand and fingers, but function was returning. On July 27, 1945, a curved incision was made along the anterior border of the sternomastoid muscle and then laterally over the proximal half of the clavicle. The

medial half of the clavicle, including its articulation, was excised subperiosteally. The attachment of the sternomastoid muscle to the periosteum of the clavicle was divided. The internal carotid artery and internal jugular vein were identified and isolated. The vertebral artery was isolated and occlusion of this vessel caused the bruit and thrill to disappear. Dissection of the vertebral artery and vein was then carried out up to the point where the vessels entered the sixth cervical vertebra. The vessels in this region were involved in scar tissue and the fistula was found to be present at this point. The proximal artery was ligated and divided. Dissection was continued until the point of entrance into the transverse process was completely isolated. It was then planned to do a mass ligation of the artery and vein at this point. As this procedure was being carried out, the artery was torn at the site of the fistula. Bleeding was controlled by digital pressure and the roof of the foramen transversarium of the sixth cervical vertebra was removed by rongeur. The interspace between the fifth and sixth vertebra was then cleared, permitting visualization of this segment of the vessels. Silk ligatures were passed about the vertebral vessels and the vessels ligated. This completely controlled the bleeding. The proximal vein was then ligated and divided. There were no postoperative complications, and no recurrence of the bruit.

CASE 8.—*A-V fistula, left vertebral vessels, first portion, due to shell fragment wounds February 28, 1945. Excision of fistula with false sac, June 15, 1945. Cured.*

This soldier received mortar shell wounds of both legs, back, and left side of the neck, on February 28, 1945. There was no excessive bleeding. He was unable to talk for four or five days following injury, but his voice gradually returned to normal. During January 1945, two attempts were made to remove foreign bodies from the neck but both attempts were unsuccessful. During an eye examination in June 1945 the presence of a bruit and thrill in the left lower portion of the neck was discovered. On admission to the Ashford General Hospital, June 15, 1945, there was a definite Horner's syndrome on the left and a partial left facial palsy. There were three small scars on the left side of the neck and beneath the superior scar a thrill was palpable. On auscultation a continuous bruit was heard. The bruit and thrill could not be obliterated by pressure occlusion of the common carotid artery. The bruit was transmitted along the course of the left transverse cervical vessels which were thought to be the site of the lesion. On August 2, 1945, a transverse incision was made over the medial half of the left clavicle and the middle third of the clavicle resected subperiosteally. A longitudinal incision was made between the two heads of the sternomastoid muscle with the lower end of the incision forming an inverted "T" with the transverse incision. The two heads of the sternomastoid muscle were separated, the carotid sheath was opened and there was no evidence of the fistula involving the carotid artery and internal jugular vein. The transverse cervical and transverse scapular arteries were isolated as they crossed the anterior scalene muscle and these vessels were traced to their origin from the subclavian as the thyrocervical trunk. The fistula did not involve these vessels. The subclavian artery was isolated medial to the anterior scalene muscle. The vertebral artery was isolated at its origin and occlusion of this vessel caused the bruit and thrill to disappear. During the dissection of the vertebral artery, the vessel was torn at its origin and it was necessary to ligate the subclavian artery proximal and distal to the origin of the vertebral. The vertebral artery and vein were then dissected distally and a false sac, measuring about 2 cm. in diameter, was encountered with the distal portion of the sac lying near the foramen transversarium of the sixth cervical vertebra. The sac was opened during the dissection and hemorrhage controlled by digital pressure until silk ligatures were passed about the distal artery and vein. After ligation of these vessels and ligation of the proximal vein there was no further bleeding. The portion of vessels containing the fistula and the false sac was excised. The thoracic duct was ligated and divided during the dissection. There were no postoperative complications and no evidence of accumulation of chyle

in the wound. His convalescence was normal and there was no recurrence of the bruit.

CASE 9.—*A-V fistula, right vertebral vessels, second portion, due to shell fragment wounds, July, 1944. Removal of transverse processes of the second and third cervical vertebrae and mass ligation of fistula, December 8, 1945. Cured.*

This soldier was wounded in July, 1944, by fragments of a high explosive shell. There was a wound below and behind the right mastoid process and a wound on the back of the right hand. He was unconcious for fifteen minutes and bled profusely from the wound in the neck. The wounds were débrided and he was returned to England where the fragment was removed from the right hand. Forty-three days after injury he was returned to combat duty. Four months later he was evacuated because of combat exhaustion. Upon routine physical examination the presence of an aneurysm of the right neck was discovered and he was returned to the United States. On admission to the Ashford General Hospital, November 21, 1945, his only complaint was that of a buzzing sensation in his right ear when lying on that side. Examination on admission showed a healed wound just posterior to the upper third of the right sternomastoid muscle. In this region a thrill was felt and a continuous bruit heard. The bruit was transmitted throughout the neck, upward behind the ear. It was easily obliterated by pressure over the right common carotid artery. Upon obliteration of the fistula the pulse fell from 80 to 72 per minute and the blood pressure rose from 120/68 to 120/80. A diagnosis of arteriovenous fistula of the internal carotid artery and internal jugular vein was made. On December 8, 1945, an incision was made parallel to the anterior border of the right sternomastoid muscle. Since it was thought that the fistula involved the internal carotid artery, the carotid vessels were identified at their bifurcation and ligatures passed about the common, internal, and external carotid arteries. Occlusion of these vessels singly or in combination did not diminish the bruit. Compression at a slightly lower level in the neck obliterated the thrill. Dissection was carried out inferiorly and the vertebral artery was identified. It was found that occlusion of this vessel stopped the bruit and thrill. Ligatures were passed about the vertebral vessels. The incision was then extended upward with detachment of the sternomastoid, longus colli, splenis capitis and levator scapulae muscles from their origins. In this manner the transverse processes of the upper two cervical vertebrae were exposed. The transverse processes of the second cervical vertebra were removed and a ligature was passed about the vertebral vessels at this point. Occlusion of the vessels did not result in cessation of the thrill. The third transverse process was similarly removed with isolation of the vessels at the level of the third cervical vertebra. Compression at this point resulted in cessation of the thrill. The vertebral vessels were then ligated at the site of the second and third transverse processes. A mass ligature was tied in the interval between these sutures with further obliteration of a segment of vessel. Slight bleeding was encountered at this time due to the tearing of small branches of the vertebral artery. A tantalum clip was applied at the site of the fistula to further insure occlusion. The vertebral artery was doubly ligated in its first portion and a tantalum clip was applied at the point at which it entered the sixth vertebra. His recovery was normal. There was no recurrence of the bruit and the condition was considered as cured on discharge two months later.

CASE 10.—*A-V fistula, left vertebral vessels, third portion, due to shell fragment wound, December 18, 1944. Preliminary temporary occlusion of vertebral artery in the first portion, removal of transverse process of the atlas, and mass ligation of the fistula, January 31, 1946. Cured.*

This soldier was wounded in action December 18, 1944, when he was struck in the left side of the neck by a shell fragment. The wound of entrance was just inferior and posterior to the angle of the mandible. There was no wound of exit. There was no excessive bleeding and no loss of consciousness. The wound was

allowed to heal by second intention. There was marked diminution in the hearing of the left ear after the injury, and he was conscious of a continuous buzzing in that ear. He was evacuated to the United States and admitted to the Ashford General Hospital on November 8, 1945. Examination revealed a scar, about 1 cm. in diameter, just inferior and posterior to the angle of the left mandible. There was a small sinus in the region of this scar from which a small amount of serous fluid could be expressed. A continuous thrill was heard over this region, which was transmitted to the base of the neck. The bruit could not be obliterated by occlusion of the common carotid artery or by pressure anywhere in the neck. A diagnosis of vertebral arteriovenous fistula was made. On January 31, 1946, a 6-cm. transverse incision was made above the medial end of the left clavicle. The two heads of the sternomastoid muscle were separated and the vertebral artery, near its origin from the subclavian, was isolated. Occlusion of the artery caused the bruit to be diminished but did not completely obliterate it. This wound was covered, and a 10-cm. longitudinal incision was made along the medial edge of the sternomastoid muscle extending from the level of the thyroid cartilage upward to the mastoid process, and then curved laterally over the mastoid process so that the sternomastoid muscle was detached at its insertion. The spinal accessory nerve was isolated and the sternomastoid muscle reflected outward and downward. The splenius capitis muscle was reflected downward from the transverse process of the atlas which exposed the vertebral vessels between the axis and atlas. Compression of the vessels in this region caused the bruit to be diminished but not completely obliterated. It was then felt that the fistula involved the third portion of the vertebral vessel. The rectus capitis muscle was detached from its origin to the transverse processes of the atlas and axis and reflected downward which exposed approximately 2 cm. of the third portion of the vessels. It was necessary to remove the transverse process of the atlas in order to adequately expose the third portion of the vessels. The vessels were mass ligated distal and proximal to the fistula with two ligatures which were passed about the vessels. This caused the thrill to completely diappear but the bruit was still slightly audible. It was assumed that there were branches between the proximal and distal ligatures. Three other sutures were passed about the vessels between the proximal and distal ligatures which caused the bruit to completely disappear. The vessels were not divided. The divided muscles were approximated with interrupted silk sutures. The postoperative course was uneventful. There was no evidence of recurrence of the bruit or thrill two months after operation.

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DISCUSSION.—DR. RUDOLPH MATAS, New Orleans, La.: Doctors Elkin and Harris have presented a contribution of outstanding merit in the surgical history of the vertebral arteries. Their experience with the arteriovenous aneurysms of these arteries is unequalled in the number of cases reported. Their anatomic studies of the vertebrals from their origin in the subclavians and their long travel to the base of the brain, inside the osseous encasement of the vertebral canal, is in accord with the physiologic importance as feeders of the medulla, and with the need for their protection against injury and accident. It is by a study of these natural defenses, so well-presented by the authors, that the comparative rarity of wounds and aneurysms of

these vessels is explained. It is because of these defenses that their surgical attack was so long delayed. For it was as late as 1836 that Sanson, of the Paris Faculty, declared that the vertebral arteries were so hidden and inaccessible that "they were beyond the reach of surgery." And so it is that it was not until 1852 that a vertebral artery was first ligated, for a gunshot wound, in a memorable operation performed by Maisonneuve and Favrot.

And it is from the viewpoint of the anatomic approaches to the vertebrals and as a contrast between the old and the new in the technic and therapy of surgery that the contribution of Doctors Elkin and Harris is especially valuable. The importance of the anatomy of the vertebral arteries for the differential diagnosis of vertebral from the carotid and deep subclavian cannot be too strongly emphasized.

It was my fortune to encounter an aneurysm of the vertebral artery very early in my surgical career. The patient, a Negro boy, age 21, was brought to my service at the Charity Hospital in July, 1888. As the result of a bullet wound, a traumatic (arterial) aneurysm, complicated by a temporary hemiplegia, developed in the right suboccipital region which was clearly differentiated from a carotid (occipital branch) injury, when the common carotid was temporarily controlled. Despite all efforts to induce coagulation by icebags, direct compression and electrolysis, the tumor continued to enlarge and compelled an operation, two months after the injury, in fear of rupture of the sac. After due preparation, the tumor was incised freely and the bleeding quickly controlled after scooping out a pseudosac of organized clot, and packing the bleeding artery in the vertebral canal of the axis. Pieces of *aseptic sea sponge* (an essential part of our surgical equipment at that time) were used very effectively to pack the osseous canal and allowed to remain as a permanent plug. The rest of the cavity was packed with iodoform gauze which remained *in situ* for five days, after which the pack was removed and the wound allowed to close. The patient made an excellent recovery as the paralytic symptoms cleared spontaneously, and was allowed to return home on the 11th day. No search was made for the bullet and the marine sponge pack remained permanently incorporated in the tissues. As a result of this experience, I wrote a monograph on "Aneurysms and Wounds of the Vertebral Arteries,"* in which the history and casuistry of these injuries is fully summarized.

Confirming the clinical rarity of vertebral wounds and aneurysms, I found, in a statistical study of the Charity Hospital, that in a total of 463,894 admissions, from 1832 to 1892 inclusive, no case of vertebral aneurysm or injury had been admitted until the patient operated upon in my service in July, 1888. Another traumatic aneurysm of the vertebral artery, in a Negro slave, had been successfully operated upon in 1849, by Dr. Warren Stone in his private infirmary, by free incision and packing. These are the only two cases (both arterial) of wounded vertebrals recorded in New Orleans up to the time of my publication in 1893, and I know of no other cases in New Orleans since that time. It is also noteworthy that only two cases of bleeding wounds of the vertebrals are recorded in a list of 245,790 gunshot wounds and 1,922 saber and bayonet wounds, in the official history of the Civil War in the United States from 1860 to 1865. It is only in modern wars, especially the two world wars, that *arteriovenous aneurysms* of the vertebral arteries began to appear. Sir George Makins reported three vertebral (arterial) aneurysms (only one operated upon) in 1,911 hospitalized British war casualties, classified according to the individual arteries injured. Hermann Kuttner, of Breslau, in a notable essay which covered the German experience of World War I, up to 1918, was able to collect only seven war aneurysms of the vertebrals in the neck, of which two were arteriovenous. Bier, despite his great authority and experience, had only one case under his care, and von Haberer, with even greater experience, had none to report.

The preponderance of arteriovenous aneurysms in modern wars over the pure arterial, especially in World War II, is easily accounted for by the enormous increase

*Annals of Surgery, Vol. 18, 477, November, 1893.

in artillery fire in which showers of small, sharp flying fragments of exploding bombs, shells and hand grenades greatly increased the liability to penetration of the best protected vascular areas.

In accord with modern experience, the mortality of the vertebral wounds is always greater in patients operated upon in the field as emergencies than in those operated upon for aneurysms, especially for arteriovenous, after recovery from the primary injury. The fact that 53 wounds and aneurysms of the vertebrals were collected from the literature up to 1893 — all were arterial and none arteriovenous — is remarkable. Eliminating 11 endocranial aneurysms as essentially postmortem findings, we find that of 20 patients who survived long enough to develop aneurysms, only six recovered — a mortality of 70 per cent. Of 22 wounds and nonaneurysmal injuries only two recovered, leaving a mortality of 90 per cent!

The wounds were almost equally divided between those caused by punctures and stabs (79.16 per cent) and gunshot injuries (78.14 per cent). This is interesting in showing the difference in pathologic effects caused by a diversity of weapons and missiles used at different periods in the history of civilian strife and organized warfare. Two notable exceptions were fatal hemorrhages caused by erosion of the arteries in tuberculous abscesses of the vertebrae.

The essential causes of death were hemorrhages, shock, sepsis, associated complications, particularly brain disorders following erroneous ligations of the common carotid artery. Practically all the cases of aneurysms and wounds that recovered were treated by packing the wound and plugging the vertebral canal. In one case in which the vertebral artery was completely divided by a bullet, there was no hemorrhage, an exception due to complete retraction and retreat of the divided artery inside the vertebral canal.

While it is probable that many of the wounded in the high vertebral (suboccipital) regions are killed outright on the field of battle, it is evident from the report of Doctors Elkins and Harris that, apart from untoward complications, the chief factors in mortality have been virtually eliminated by modern practice in patients who have survived the effects of the primary injury.

While no attempt was made to make a special statistical study or record of vascular surgery in the United States history of World War I, the deficient records of vascular experience in that war have been more than compensated for by the magnificent contributions to surgical knowledge that have sprung out of the experience of the Army Vascular Centers so wisely organized by the Surgeon-General, of which the Ashford General Hospital at White Sulphur Springs, under the direction of Colonel Elkin, will remain a monumental example.

DR. WILDER PENFIELD, Montreal, Quebec: I would like to add to Doctor Elkin's approach one other method which we found necessary a few months ago in aneurysm of the vertebral artery. This was in a patient who had von Recklinghausen's disease. There was no bruit and we assumed there was an intraspinal neoplasm. However, I found at the level of the second cervical vertebra an arteriovenous aneurysm within the canal but outside the dura. I carried out laminectomy and ligated the vertebral artery below, between C–5 and C–6, making the approach posteriorly, and then packed the aneurysm with gelatin sponge, making an opening in the dura. It looked satisfactory when we stopped, but the patient was not relieved of pain in the neck and the paraplegia continued to advance. Therefore, we went in again, making a lateral cerebellar approach, and tied the vertebral artery near the pons, and had a completely satisfactory clinical result. I question whether the approach of Doctor Elkin would have been safe at that high level, even if we had been able to make the diagnosis beforehand.

# STUDIES ON THE USE OF GELATIN SPONGE OR FOAM AS AN HEMOSTATIC AGENT IN EXPERIMENTAL LIVER RESECTIONS AND INJURIES TO LARGE VEINS*

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THE MAJOR CONTRIBUTIONS in the field of absorbable hemostatic agents which have been made by Ingraham and Bailey[1] on fibrin foam and by Frantz[2] on oxidized cellulose have been received with considerable interest by the surgical profession. An additional hemostatic agent, gelatin sponge, has recently been described by Correll and Wise,[3] and has since been the subject of papers by Pilcher and Meacham,[4] Light and Prentice,[5] and Correll, Prentice, and Wise.[6] The work of these authors has established this material as a valuable addition to the field of hemostatic substances.

Gelatin sponge has been of interest to us from the standpoint of the general surgeon and studies on its absorption[7] and hemostatic[8] action have been reported. The excellent hemostatic properties of gelatin sponge has led us to further studies of a more critical nature. A preliminary report on part of this work has been presented.[9]

In a series of 12 dogs, which were operated upon with aseptic technic, and under ether anesthesia, a considerable portion of a lobe of the liver was resected by simply cutting it off with scissors. The gelatin sponge was prepared for use by moistening in physiologic saline solution, expressing the air, and then removing the excess saline by compressing between dry gauze. No thrombin was added to the gelatin sponge in this series of animals. The large gelatin sponge was placed over the freely bleeding stump of liver so that it overlapped the upper and lower surface of the liver. (See Plate IA, showing hemorrhage from resection of portion of lobe of liver and its complete control by application of gelatin sponge.) The sponge was held in place with firm pressure for five to ten minutes. Care was taken to obtain good apposition of the sponge to the bleeding surface, as this produced a relatively rapid adhesive effect between the raw surface of the liver and the sponge.

Hemostasis was obtained in all of these animals by the application of the gelatin sponge alone, without any supplementary suturing. It was necessary, however, to reapply a fresh gelatin sponge in several instances to obtain complete hemostasis. All of these animals survived the immediate postoperative period. Two of the animals died at four and five days, respectively,

* This work was aided, in part, by a grant from the Upjohn Co. to the University of Chicago.

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from what appeared to be a bile peritonitis. The other animals were sacrificed at varying periods of time from two days to six weeks after the operation. There was no evidence of secondary hemorrhage from the liver in this series.

At autopsy, the gross appearance of the liver and the condition of the sponge varied according to the length of time after operation. (See Fig. 1A and B, showing photographs of specimens of liver and gelatin sponge at different lengths of time after operation.) Within the first four days the gelatin sponge was a red friable soggy mass which was quite firmly adherent to the liver stump. In attempting to remove it from the liver the sponge would usually fragment. Light fibrinous adhesions would usually be present between the sponge and the omentum or surrounding structures.

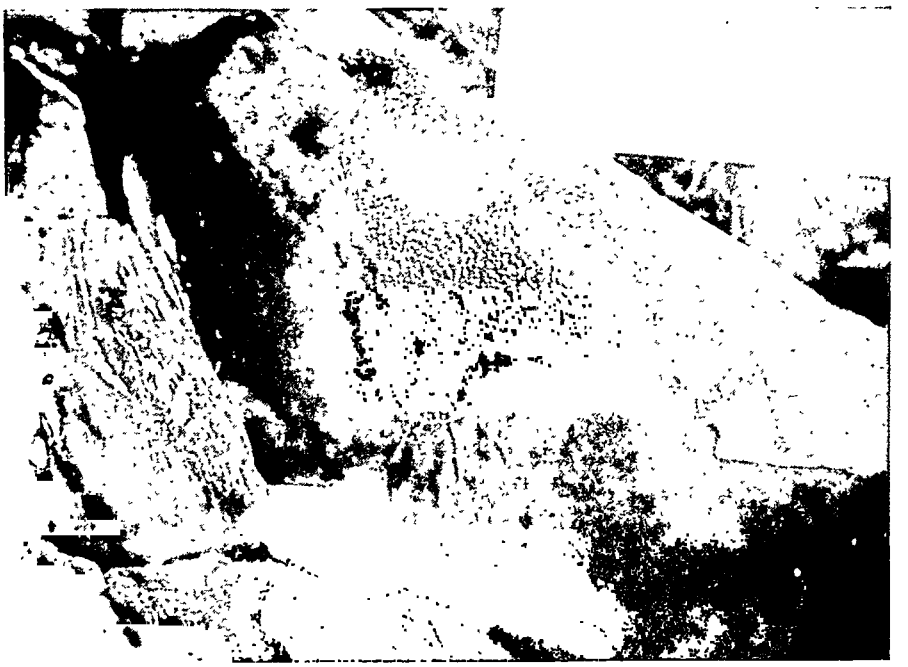


FIG. 1-A.—Showing specimen of liver at 8 days, with gelatin sponge covering raw surface.

After about a week the gelatin sponge became more firm and tough and sometimes had a glassy gelatinous appearance. Adhesions of varying magnitude would often be present but could usually be easily separated. After two weeks the gelatin sponge was usually covered by adhesions to omentum or surrounding organs which were difficult to separate without opening into the gelatin sponge mass which was well-encapsulated between the stump of liver and surrounding structures. After three weeks the gelatin sponge was usually buried in some adhesions which were often less than observed earlier. After four weeks or more the gelatin sponge was not easily identified and the stump of the liver was usually quite well healed over although often buried in some adhesions to surrounding structures.

The microscopic studies presented some rather interesting points. During the first few days there was a slight but not conspicuous leukocytic reaction to the sponge. After a week there was evidence of very active

fibroplasia across the stump of liver under the cover of the gelatin sponge. (See Plate IIA, B, C and D, showing photomicrographs of the gelatin sponge covering the healing stump of liver at varying periods of time after operation.) This fibroplasia appeared to extend into the interstices of the sponge which were filled with red blood cells. There was beginning absorption of the sponge adjacent to this area of fibroplasia. After two weeks there was more mature fibroplasia which invaded the sponge to a greater extent and which has resulted in encapsulation of the sponge. There was evidence of some absorption along the entire periphery of the sponge although there was little change in the central portions of the sponge. After three weeks the fibroplasia has resulted in fairly well-differentiated connective tissue covering

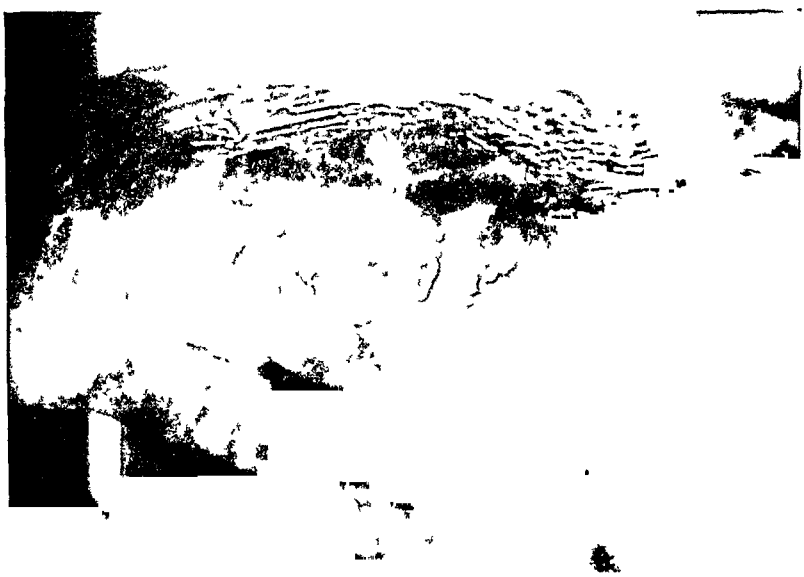


FIG. 1-B.—Showing liver after 1 month with healing of stump of resected lobe and disappearance of the sponge surface.

of the stump of the liver and there is evidence of more advanced absorption of the sponge and invasion of the interstices by macrophages. After a month or more there may be no evidence of gelatin sponge or there may be a well-encapsulated residuum which is in an advanced stage of absorption.

The second series of experiments on the hemostatic action of gelatin sponge consisted of producing wounds in large veins to determine whether such massive venous hemorrhage could be controlled. In a series of 36 dogs, which were operated upon with aseptic technic, and under ether anesthesia, the femoral, jugular, or renal veins or the vena cava were exposed. A stab incision was made with a scalpel or a portion of the wall of the vein was excised. The latter procedure was preferred as it gave a more massive hemorrhage. (See Fig. 2 and Plate I, showing hemorrhage from femoral vein and from vena cava which was controlled by application of gelatin sponge.) The gelatin sponge was applied immediately to the bleeding vein and pressed firmly in place over the wound for one to two minutes. It was found that pressure with the gloved finger directly on the sponge on the vein was more satis-

A



B







C

D

PLATE I

PLATE I.—A.—Showing hemorrhage from liver resection

B.—Showing control of hemorrhage by application of gelatin sponge over bleeding stump of liver.

C—Showing hemorrhage from vena cava (column of blood caught by camera before splashing back on wound).

D—Showing control of bleeding by application of gelatin sponge

factory than pressure transmitted through saline-soaked gauze which required subsequent removal and sometimes dislodgement of the gelatin sponge. Improvements in the technic of applying pressure will undoubtedly be worked out in subsequent studies. The bleeding was completely controlled in all experiments except two. These two failures were in the series of 22 experiments where the wound was made in the abdominal portion of the inferior vena cava. Of the four experiments where the wound was made in the thoracic portion of the inferior vena cava and the two experiments on the superior vena cava there was one secondary hemorrhage from the latter. This was apparently due to the motion of the lungs which dislodged the sponge after the chest wound was closed. In the experiments on the abdominal vena



FIG. 2-A.—Showing hemorrhage from femoral vein of dog.

cava a layer of peritoneum was closed over the sponge which thus apparently prevented subsequent dislodgment in this series.

The animals were sacrificed at varying periods of time from 12 hours to 60 days after operation. Within 12 hours the gelatin sponge was firmly adherent to the wall of the vein. (See Fig. 3, showing vena cava.) The defect in the wall of the vein could be readily identified up to five days, or more, with the gelatin sponge forming a well-sealed patch over the defect. After six to eight days there was often a thin transparent membrane covering the gelatin sponge which was plugging the rent in the vein. After eight to twelve days the wound in the vein usually appeared to be closing over. After three weeks there was evidence of an endothelized scar. In some instances where a small incision was made in the vein instead of removing a small segment of the wall of the vein it was difficult to identify the point where the wound had been made after two weeks or more. In two of the experiments where the animal



FIG 2-B.—Showing control of hemorrhage from femoral vein by application of gelatin sponge "patch."

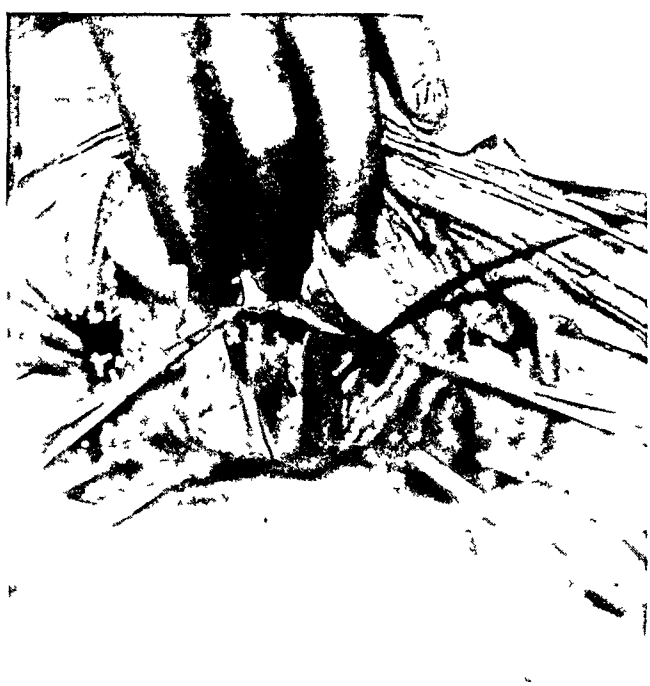
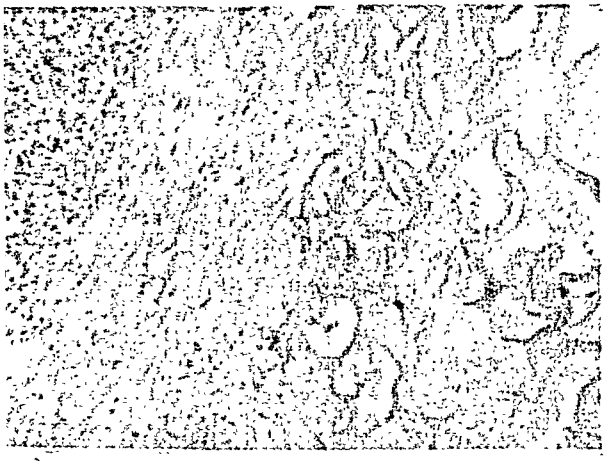


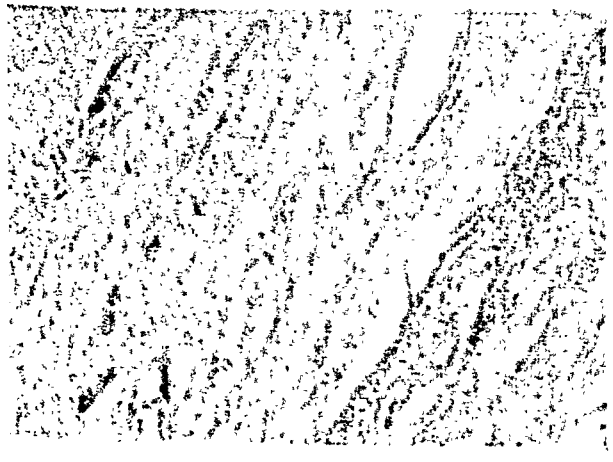
FIG. 2-C.—Showing hemorrhage from vena cava of dog.

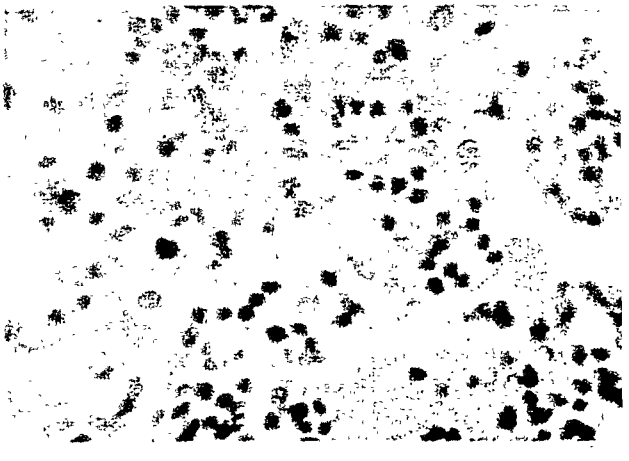
A



B







C

D

PLATE II

PLATE II.—A.—Showing photomicrograph of healing stump of liver, with active fibroplasia at 8 days, covered by gelatin sponge which is being invaded by fibroblasts.

B.—Showing photomicrograph of liver at 2 weeks, with more advanced fibroplasia over liver stump and invasion of sponge which forms protective cover over this reparative process.

C.—Showing photomicrograph of liver at 3 weeks, with evidence of more advanced differentiation of the connective tissue, and invasion of the sponge with macrophages, mononuclears, and leukocytes. There is also connective tissue deposited in the sponge interstices and moderate degree of absorption of the sponge.

D.—Showing advanced absorption of sponge after one month. A few spicules of the sponge can be seen, there is invasion by macrophages, lymphocytes, and some polymorphonuclear leukocytes.

was sacrificed within a few days there was a small clot adherent to the sponge plugging the wound of the vein. In another instance there was an organized thrombus adherent to the vein wall where the wound had been produced sixteen days previously. This did not produce occlusion of the vessel. In one animal there was moderate constriction of the lumen of the vein where a large oval shaped segment of vein wall was removed twenty-six days previously and the defect covered with a gelatin sponge patch. In several other experiments where a moderate sized piece of vein wall was removed there was no apparent constriction. The gelatin sponge could usually be readily identified during the first week. After one to two weeks the sponge became surrounded by a capsule of fibrous tissue. After a month it was usually difficult to identify the gelatin sponge grossly.



FIG. 2-D.—Showing control of hemorrhage from vena cava by gelatin sponge "patch" three minutes after application.

In addition to these experimental studies, we have used gelatin sponge on 76 patients. Satisfactory hemostasis has been obtained with the sponge in a variety of surgical procedures where troublesome bleeding could not be completely controlled by other means. The magnitude of the bleeding which occurred in these procedures was rarely comparable to that which was obtained in the series of experimental procedures and, therefore, our clinical tests do not represent as critical an evaluation of the hemostatic properties of the gelatin sponge as our experimental tests.

COMMENT: In our observations on gelatin sponge it would appear that a substantial part of the hemostatic action may be due to the spongy material itself. It is possible that the enormous surface-area of the myriads of interstices may attract and damage the platelets in the blood which enters the

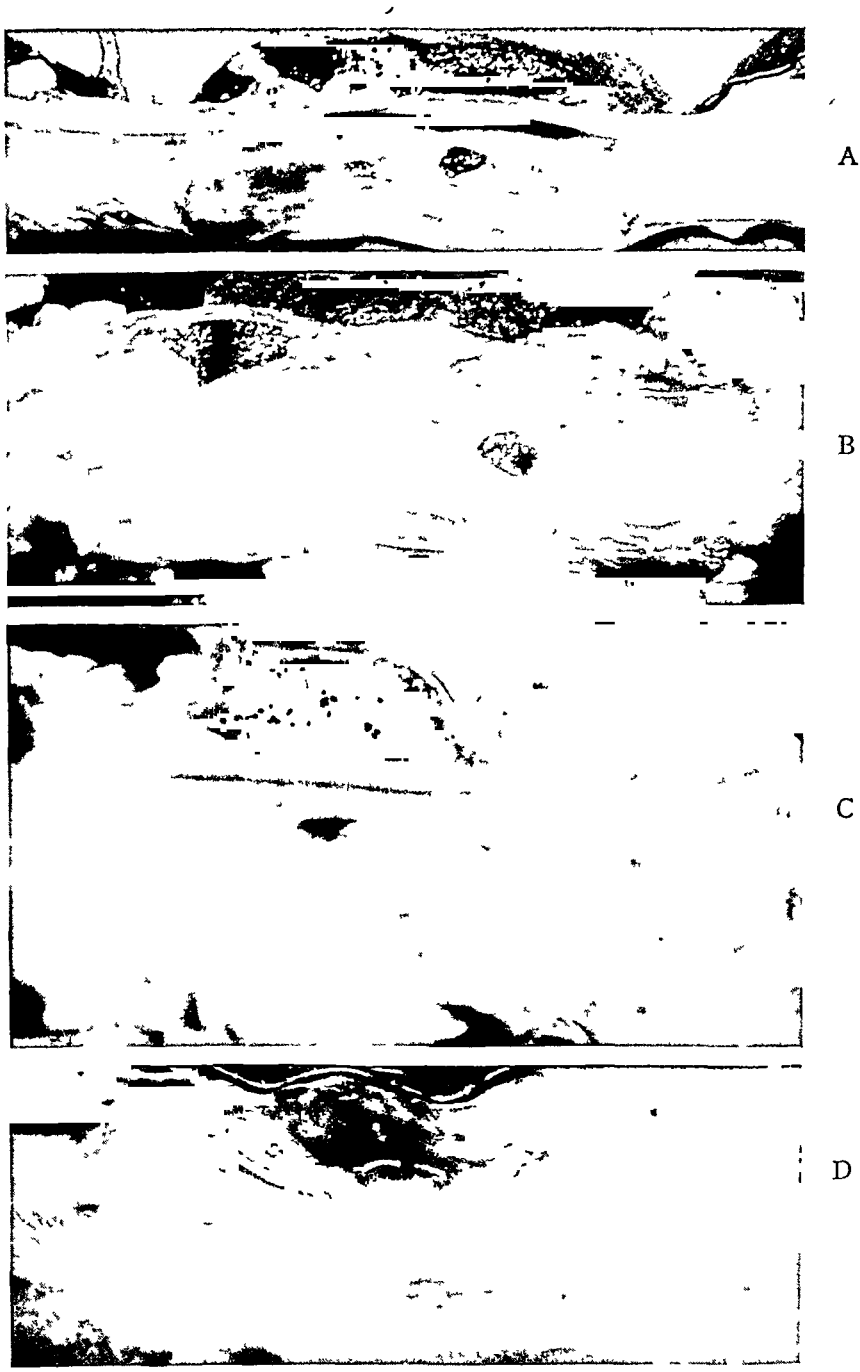



FIG. 3-A.—Showing specimen of vena cava 12 hours after application of gelatin sponge "patch" which firmly seals off a large and a small wound in the wall of the vessel.

B.—Showing vena cava four days after gelatin sponge "patch" for wound in wall of vessel.

C.—Showing vena cava 8 days after gelatin sponge "patch." The sponge has become encapsulated on the tissues surrounding the vein, and the defect in the wall of the vein is closing over.

D.—Showing vena cava 28 days after "patch." There was a fairly large wound which has healed over leaving an endothelized scar.

sponge, thus, liberating thromboplastin. This in combination with the calcium and prothrombin in the blood may elaborate enough thrombin to initiate the clotting mechanism. The addition of prepared thrombin undoubtedly enhances and accelerates the hemostatic action of gelatin sponge, but we are not prepared to estimate the extent to which it does so. In the clinical use of gelatin sponge it is, therefore, recommended that thrombin be used to obtain the maximum hemostatic effect.

Our observations on the use of gelatin sponge in controlling bleeding in experimental liver resections and in clinical biopsies would suggest the possibility of using this material to control bleeding as a result of resection of tumors of the liver in patients. We are not as yet prepared to make this recommendation until further details in the technic of applying the sponge have been worked out. Furthermore, it would be desirable to have a somewhat stronger and tougher spongy material than is now available. This would make it possible to suture the sponge to the upper and lower surface of the liver by some sort of basting-stitch to securely hold it in place. Although the absorption time of the sponge which we have used may be more than adequate under favorable conditions it must not be overlooked that the sponge may become rapidly liquefied in the presence of a considerable concentration of leukocytes. This may account for the two cases of bile peritonitis in our experimental series, as the rapid liquefaction of the sponge would remove any barrier to the outpouring of bile from the intrahepatic ducts which otherwise remained sealed-off by the gelatin sponge until healing occurs.

The excellent protective cover which the sponge appears to offer to the healing process across the stump of liver at the line of resection is of considerable interest as is also the structural support it seems to give the reparative process. This is a rather fundamental point which deserves further study as it is quite unusual for any foreign material to aid the normal process of repair.

The principle of utilizing a patch of hemostatic material to control bleeding from large dural sinuses has been practically a standard technic among neurosurgeons since the introduction of muscle patches or stamps by Cushing in 1911.[10] As a result of the work of Ingraham and Bailey, fibrin foam has largely replaced the muscle-patch technic in the past few years. Recently, Pilcher and Meacham, and Light and Prentice, have demonstrated that gelatin sponge can be utilized as effectively as fibrin foam for this patch technic in controlling bleeding from the dural sinuses.

Our observations on the gelatin sponge-patch technic for controlling massive bleeding from the large veins of the dog have not been carried on over a sufficient period of time or in sufficient number to as yet justify a recommendation on its clinical use by the general surgeon. A number of situations naturally suggest themselves where this technic would be of value.

In resections of the pancreas the superior mesenteric or portal vein may be injured in the course of dissecting away adherent tissue. This would be an especially suitable place for the application of gelatin sponge to pre-

serve the continuity of this vessel which one would not choose to ligate if there was any other alternative. In radical dissections of the neck or axilla one may find occasion to utilize such a patch technic if the jugular or axillary veins were opened during the course of the operation. Occasionally during thyroidectomy one may tear a lateral thyroid vein in mobilizing a large gland. If one is unable to get exposure of the bleeding vessel due to the large overlying gland the gelatin sponge would probably offer an alternative of value. There are innumerable conditions other than these where an absorbable hemostatic agent might prove helpful if not life-saving.

Wherever one can easily suture a rent in a major vein it is of course the procedure of choice and should take precedence over the application of an absorbable hemostatic patch. However, there may be value even here in utilizing gelatin sponge as a reinforcement to the suture line in the blood vessel.

The possibility of a propagating thrombus arising from the sponge plugging the rent in a vein must be considered as a possibility in the clinical application of this study. The use of heparin and dicoumarol therapy after operation may be required to prevent this eventuality. On the other hand, the experience of neurosurgeons with the patch technic, using muscle, fibrin foam, or gelatin sponge, on the dural sinuses has generally been quite good as they do not have a problem of subsequent thrombosis of these veins.

## CONCLUSIONS

In view of our experimental observations in which we have been able to control extensive venous hemorrhage from liver resections as well as from direct injury of large veins, including the vena cava, it would appear that gelatin sponge has excellent hemostatic properties. An absorbable substance with these properties should find many uses in the hands of the general surgeon. There are, as yet, a number of points which should be worked out in the technic of handling this material to obtain the best results. In addition, it would appear that there may be a place for a spongy material with different degrees of absorbability as well as tougher and stronger physical properties which would lend itself to special uses. The particular promise which these hemostatic substances have to offer is that it may enable one to undertake more extensive surgery with greater safety, especially in the treatment of carcinoma, than has been feasible in the past.

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Note: The authors wish to express their appreciation to Dr. Eleanor Humphreys of the Dept. of Pathology of the University of Chicago and to Dr. Ormand Julian of the Dept. of Surgery of the University of Illinois College of Medicine and the Chicago Memorial Hospital for their participation in some phases of this work, and also to Dr. Edward Senz and Dr. Howard Owen.

DISCUSSION.—DR. WILLIAM JASON MIXTER, Boston, Mass.: I would just like to say that we who are doing neurosurgery can corroborate what has already been said, and I believe this will be a definite advance in general surgery as well as surgery of the brain. In surgery of the spinal cord there is one point of interest. I have been able to inspect three different specimens of gelatin foam in patients who were subjected to second laminectomies later. There seemed to be a smoother cleavage between the gelatin foam and the dura than there has been in the past where muscle was used to control bleeding from the dural veins. I think it is a definite step in advance. Fibrin foam works in the same manner.

DR. HILGER P. JENKINS, Chicago, Ill. (closing): I had planned to pay tribute in this presentation to Dr. Harvey Cushing for his introduction of the muscle "patch" which has been part of the standard technic of the neurosurgeon until the advent of the fibrin foam and subsequently the gelatin sponge. (This is covered in the manuscript but not mentioned because of the time limitation.) It behooves the general surgeon to take note of the technic of the neurosurgeon in controlling hemorrhage from veins by the "patch" technic, especially where one would not wish to sacrifice the vein by ligation or where ligature or vein suture may not be feasible.

# PENICILLIN IN THE TREATMENT OF ESTABLISHED SURGICAL INFECTIONS*

## A SYSTEMATIC STUDY OF 744 INCLUDING 82 SEPTICEMIAS

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IN THE FALL OF 1943 when penicillin became available for clinical study, the Committee on Chemotherapy of the National Research Council assigned a limited quantity to several of the units which had been studying the prevention of infection in civilian accidental wounds and burns under the direction of the Subcommittee on Surgical Infections. These units then undertook to observe the effect of penicillin in the treatment of established surgical infections. These cases were reported to Doctor Keefer and they have been included in the all-inclusive reports which he has made from time to time, but the Subcommittee on Surgical Infections believed that it would be profitable to study the surgical cases separately, going into the details of the cases and recording in a systematic manner the circumstances of each case with the hope that a review and analysis of a fairly large number, might determine what circumstances contributed toward and what circumstances interfered with, a favorable outcome. It was thought that this might logically lead to methods of treatment which would improve the results by increasing the favorable circumstances and eliminating the unfavorable factors.

With the advice and council of Drs. Lowell Reed and John Fertig, Chairman and member, respectively, of the Subcommittee on Biostatistics of the National Research Council, the Subcommittee on Surgical Infections devised a summary sheet on which the items were listed which, it was thought, might play an important rôle in determining the outcome of the treatment. A copy of the summary sheet is enclosed with this report. The chief items have to do with the diagnosis of the surgical infection, its duration and its seriousness before instituting penicillin treatment, the nature of the previous surgical and drug therapy, the dosage and duration of penicillin and the method of its administration, the nature of associated medical or surgical treatments, the clinical symptoms and signs of infection and their persistence or disappearance, and the bacteriologic analyses before and after penicillin treatment. Finally, a well-considered judgment regarding the value of penicillin, in view of the previously noted factors, was recorded in each individual case.

The Committee recognized that there is often a great deal of difficulty in estimating the rôle played by any drug when it is used in conjunction with a surgical procedure, for a condition which in times past may have

* Work done under contract with the Office of Scientific Research and Development.
Read before the American Surgical Association, April 2-4, 1946, Hot Springs, Virginia.

responded satisfactorily to the surgical procedure alone. Surgical infections differ from medical infections in certain fundamental respects which make them less likely to respond to drug treatment. These differences have been described in detail in a number of recent publications but they may be profitably enumerated here because they must be considered in the appraisal of penicillin or of any other drug. Surgical infections are characterized by (1) a local spontaneous or traumatic breakdown of tissue or a localized exudation of leukocytes either into a body cavity, such as a joint or the pleura, or into the substance of solid tissues or organs, such as muscle or liver. This broken down tissue or cellular exudation must either be evacuated or absorbed before health is restored. (2) The blood vessels in the wall of an abscess are thrombosed and any medication coming *via* the blood stream may have difficulty penetrating or diffusing into the focus far enough to reach the offending organisms. (3) At the same time, in a well-localized lesion, the opportunity is afforded for the local application of the drug in question. (4) The bacterial species in surgical infections are often multiple and there may be a synergistic action between them. One or more of the species in any given infection may be either resistant to the bacteriostatic action of the drug or antagonistic to it. (5) When surgical infections are under control there is always the necessity for removal of the débris and repair of the tissue which may require more nutritive elements than are needed for the recovery from a medical infection. (6) Spontaneous surgical infections in contradistinction to those following injury are in the very beginning, before there has been any breakdown of tissue, similar to medical infections, in other words, there is a diffuse inflammation which may be called a cellulitis. Some surgical infections remain in the stage of cellulitis for several days and the tissue breakdown is slow. In others it is rapid. If drugs can be given before there is a breakdown of tissue it is reasonable to believe that they do not meet with the difficulties mentioned above but have a more favorable opportunity to contact and control any susceptible organisms.

The Subcommittee also realized that the complexity of a surgical infection made it almost impossible to run concurrently, a series of controls without any drug treatment or with some other form of drug treatment, the number of factors in any given case being so great, the time factor alone (duration of the infection before treatment) being infinitely variable. Surgical infections may be acute or chronic and there is no sharp line between them. The committee arbitrarily chose 30 days as the dividing line. Among the chronic cases there are those which go on for months or years without much change and those with acute exacerbation so that they must be classified as both acute and chronic. This is particularly true in cases of osteomyelitis. During the course of any chronic infection there may have been any number of operations as well as numerous local and general forms of medication — no two cases being alike. It is, therefore, impossible to obtain for study two parallel series, either by a process of alternating all cases or

by selecting two similar cases and assigning one to the treated series and the other to the control series.

In such circumstances the Subcommittee felt that it would be necessary to let certain chronic and subacute cases, in their previous course, be their own controls. In other cases it would be necessary to show some results in the drug-treated patients not seen in previous surgical experience when the drug under study was not available. For example, when an infection remains for days or weeks or months *in statu quo* or goes progressively down hill and then shows an abrupt improvement following the administration of a drug, it is reasonable to believe that the drug was responsible for the change. If this happens, not once, but many times it becomes more and more convincing. In the category of results not previously seen, we may list: (1) Those cases of surgical infection, formerly always requiring a surgical procedure, in which that procedure was completely obviated. (2) Those cases in which a limited surgical procedure with the aid of drug sufficed to effect a cure when formerly, without drug, a radical procedure would have been necessary. (3) Those cases requiring a surgical procedure but in which the healing time was definitely shortened by the use of drug. (4) Those cases permitting primary closure after incision or excision concurrently with the administration of drug and (5) those cases permitting an earlier successful secondary closure with drug than could have been obtained without drug.

In any group of surgeons there might be a difference of opinion regarding the classification of cases in any of these five categories. For example, in a case of cellulitis one might say that surgery was obviated, while another might say that he had seen similar cases which subsided spontaneously. Probably there would be more unanimity of opinion with reference to a condition such as acute suppurative arthritis which formerly almost invariably required incision and drainage to effect a cure and a return to normal function. There might be the greatest difference of opinion about cases in the third category, that of the shortening of healing time because no one can tell how long any given case will take to recover. One can estimate the healing time of a carbuncle following incision or excision but in both drug-treated and non drug-treated carbuncles there must be a separation of the tissue already destroyed when treatment began. This tends to equalize the healing time for cases in the two groups. The value of the drug treatment can sometimes be more clearly indicated by the disappearance of the causative organisms from the culture during the course of therapy, for in non drug-treated cases the cultures are almost invariably positive until the wound is healed.

Primary closure of a wound which has been made for the drainage of a purulent exudate was rarely successful before the advent of drugs. If that can now be done repeatedly with the aid of a drug, we may be fairly certain of the drug's efficiency. Secondary closure was not infrequently successful in World War I after a wound had been cleared of its slough and had been covered with healthy granulations. If with the aid of drug now there can be a strikingly higher percentage of successful wound healing or if sec-

ondary closure can be done earlier than formerly, the drug must be given credit for its share in the successful result. This is probably the most difficult criterion to weigh and measure accurately, in any particular case.

Bearing all of these things in mind, it is obvious that it may be difficult to appraise the value of a drug in any given case. However the Subcommittee felt that some approach to a satisfactory estimate could be made with regard to penicillin if the results could be classified as follows:

1. *Excellent* in cases responding abruptly or definitely within the first 72 hours after treatment began.
2. *Good* in cases clearly showing the benefit of the drug but over a longer period of time, perhaps a week or ten days.
3. *Questionable* in cases which might have done just as well without the drug as a result of the surgical procedure or some other associated treatment.
4. *No effect* in cases in which the infection was not altered in any way but ran its usual course.

These criteria were followed in the cases herewith presented. The largest single group of cases were observed by the author, and his associates, Dr. Harold Harvey and Dr. Robert H. E. Elliott at the Presbyterian Hospital in New York City. The next largest group were studied at the Pennsylvania University Hospital in Philadelphia by Dr. John Lockwood, Dr. Jonathan Rhoads and Dr. William White. The third largest group was cared for by Dr. William Altemeier at the Cincinnati General Hospital. The rest of the cases in smaller groups were treated in Detroit Receiving Hospital by Dr. John Hirshfeld, and his associates, at the Henry Ford Hospital by Drs. McClure and Lam and at the Charity Hospital by Drs. Ochsner and Caldwell, and their staffs. It has not seemed profitable to divide the cases into groups according to the units studying the problem. It may be assumed that they were treated in a similar manner and the summary sheets make certain that the factors associated with the case were recorded in a uniform manner. These data have been transferred to the McBee System punch cards for the purpose of analysis and the results of the study are given below.

There were approximately 1,000 cases of established surgical infections treated in all of the units put together. Approximately one-quarter of these cases were treated with various forms of sulfonamide or with zinc peroxide or some other antibacterial agent, but the treatment was too diversified to warrant analysis. This presentation will be limited to the cases which were treated with penicillin of which there were 744 with data sufficiently complete to yield a satisfactory analysis. These cover a wide variety of surgical diagnoses.

The accompanying tables give a list of the surgical lesions represented by five or more cases. The results are given in percentages in the four categories of "Excellent," "Good," "Questionable," and "No Effect." The first two may be considered favorable and the last two unfavorable. In the

Questionable group there may be cases in which the penicillin played a favorable rôle but it was not apparent to the observers and so we cannot score them to the credit of the drug.

It will be seen in Table I, giving the results for the series as a whole, that penicillin is of benefit in surgical infections and yet it is not a panacea. In about 15 per cent of the cases the response could be called dramatic or excellent, in 50 per cent definite or good, in 18 per cent doubtful or questionable, while in 18 per cent no effect could be demonstrated. It is necessary to study the cases carefully from many angles to determine what the conditions are for its success and why it often fails.

When the cases are divided into diagnostic groups it is seen that the results in some are very good, in others, intermediate and in others, poor.

TABLE I

SHOWING THE OVER-ALL RESULTS OF PENICILLIN TREATMENT IN SURGICAL INFECTIONS

| | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|
| | Favorable | | | Unfavorable | | |
| Total Number of Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| 744 | 14.8 | 49.9 | 64.7 | 17.8 | 17.6 | 35.4 |

TABLE Ia

SHOWING THE MOST FAVORABLE RESULTS OF PENICILLIN TREATMENT ACCORDING TO DIAGNOSIS

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| Furuncle | 26 | 53.9 | 38.4 | 92.3 | 7.7 | 0 | 7.7 |
| Cellulitis | 36 | 64.0 | 27.7 | 91.7 | 8.3 | 0 | 8.3 |
| Mastoiditis | 6 | 0 | 83.3 | 83.3 | 0 | 16.7 | 16.7 |
| Carbuncle | 28 | 39.3 | 42.9 | 82.2 | 14.3 | 3.6 | 17.9 |
| Suppurative arthritis | 22 | 18.2 | 63.5 | 81.8 | 4.5 | 13.6 | 18.1 |
| Lung abscess | 11 | 0 | 81.7 | 81.7 | 0 | 18.3 | 18.3 |
| Superficial abscess | 32 | 25.0 | 56.3 | 81.3 | 6.3 | 12.5 | 18.8 |
| Brain abscess | 5 | 0 | 80.0 | 80.0 | 0 | 20.0 | 20.0 |
| Osteomyelitis | 153 | 8.5 | 68.0 | 76.5 | 13.7 | 9.8 | 23.5 |

These are shown in Tables Ia, and Ib and Ic. Table Ia indicates that the best scores in the favorable columns were obtained by furuncles, cellulitis, mastoiditis, carbuncles, suppurative arthritis, lung abscess, superficial abscess, brain abscess and osteomyelitis, in that order, all of these lesions responding favorably in more than 75 per cent of the cases. The most brilliant results were obtained in the cases with cellulitis or furuncles and it is of interest that these two diagnoses are the only ones with zero in the "no effect" column.

The intermediate group shown in Table Ib includes deep abscess, thrombophlebitis, sinusitis, infected soft-part wounds, infected operative wounds, otitis media, infected compound fracture and ulcers of the skin. Favorable results were obtained in from 50 per cent to 75 per cent of these cases.

The poorest results, revealed in Table Ic, were obtained in empyema, burns, gas gangrene, actinomycosis, gangrene of the skin, miscellaneous surgical infections, postoperative pneumonia, peritoneal abscess, and, worst of all, diffuse peritonitis.

TABLE Ib

SHOWING THE INTERMEDIATE RESULTS OF PENICILLIN TREATMENT ACCORDING TO DIAGNOSIS

| Diagnosis | Total Cases | Results in Percentage: Favorable: Excellent | Favorable: Good | Favorable: Combined | Unfavorable: Questionable | Unfavorable: No Effect | Unfavorable: Combined |
|---|---|---|---|---|---|---|---|
| Deep abscess | 58 | 15.5 | 53 4 | 68.9 | 22.4 | 8 6 | 31 0 |
| Thrombophlebitis | 12 | 8 3 | 58.4 | 66 7 | 16 7 | 16 7 | 33 3 |
| Sinusitis | 6 | 0 | 66.7 | 66.7 | 0 | 33 3 | 33 3 |
| Infected soft-part wound | 37 | 13 5 | 51.3 | 64.8 | 21.6 | 13.5 | 35.1 |
| Infected operative wound | 70 | 5 7 | 55.6 | 61.3 | 21.4 | 17 2 | 38 6 |
| Otitis media | 7 | 28 6 | 28 6 | 57.2 | 14.3 | 28 6 | 42.9 |
| Infected compound fracture | 9 | 0 | 55 6 | 55.6 | 11.1 | 33.3 | 44 4 |
| Ulcer of the skin | 22 | 0 | 50.0 | 50 0 | 18.2 | 31.6 | 50 0 |

TABLE Ic

SHOWING THE LEAST FAVORABLE RESULTS OF PENICILLIN TREATMENT ACCORDING TO DIAGNOSIS

| Diagnosis | Total Cases | Results in Percentage: Favorable: Excellent | Favorable: Good | Favorable: Combined | Unfavorable: Questionable | Unfavorable: No Effect | Unfavorable: Combined |
|---|---|---|---|---|---|---|---|
| Empyema | 34 | 0 | 47 0 | 47.0 | 26 5 | 26 5 | 53.0 |
| Infected burn | 31 | 3.2 | 42 0 | 45 2 | 29 0 | 25.8 | 54.8 |
| Gas gangrene | 9 | 11.1 | 33 3 | 44 4 | 33.3 | 22.2 | 55.5 |
| Actinomycosis | 7 | 0 | 42 9 | 42.9 | 28.6 | 28 6 | 57.2 |
| Gangrene of skin | 10 | 10.0 | 30.0 | 40 0 | 50 0 | 10.0 | 60 0 |
| Miscellaneous | 66 | 13 6 | 25 8 | 39 4 | 16 7 | 43.9 | 60 6 |
| Postop. pneumonia | 18 | 11.1 | 27 8 | 38 9 | 38 9 | 22.2 | 61 1 |
| Peritoneal abscess | 11 | 9.1 | 27 3 | 36.4 | 45 5 | 18 2 | 63 7 |
| Diffuse peritonitis | 18 | 5.5 | 22 2 | 27.7 | 22.2 | 50.0 | 72 2 |

All of these groups must be broken down in order to determine if possible why some cases succeeded and some failed, but first it would seem profitable to present the other factors which may play a rôle in the favorable outcome. It is generally believed that penicillin is more effective in acute than in chronic infections. Our cases may be divided into acute, chronic, with acute exacerbation, and chronic, without flare-up. The results are shown in Table II and they bear out the general impression but the difference is not as great as one would suppose. The chief difference is not in the combined figures for favorable results but in the figures for a prompt response in the "excellent" column. This clearly indicates that a larger pro-

portion of the acute cases respond dramatically to penicillin. Furthermore, the chronic cases with an acute exacerbation seem to give better results than those which smolder along without much change. However, other factors come into play in these two groups (particularly the nature and time of a surgical procedure) so that the over-all figure should not be given too great weight because these groups are not really comparable.

TABLE II

SHOWING THE RESULTS ACCORDING TO THE ACUTENESS OF THE PROCESS

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| Acute | 477 | 20.1 | 46.6 | 66.7 | 17.4 | 16.0 | 33.4 |
| Chronic, with acute flare | 49 | 8.2 | 63.3 | 71.5 | 14.3 | 14.3 | 28.6 |
| Chronic, without acute flare | 218 | 4.6 | 54.1 | 58.7 | 19.3 | 22.0 | 41.3 |

TABLE III

SHOWING THE RESULTS IN THE ACUTE CASES ACCORDING TO THE DURATION OF SYMPTOMS BEFORE INITIATING TREATMENT

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| Four days or less | 145 | 26.9 | 43.4 | 70.3 | 14.5 | 15.2 | 29.7 |
| Five days or more | 319 | 17.9 | 47.6 | 65.5 | 19.1 | 15.4 | 34.5 |

In the acute cases the duration of the infection before the initiation of treatment bears an important relationship to the favorable outcome as is shown in Table III. In the chronic cases other factors are of more importance.

Of these cases, 662 were considered serious infections and 82 trivial. Favorable results were obtained in 64.9 per cent of the serious and in 88.6 per cent of the trivial cases. Of 384 cases which had received some form of sulfonamide prior to penicillin treatment, 65.4 per cent showed a favorable response. One would have expected that the cases which had failed to respond to the sulfonamides or to other drugs would have responded less readily to penicillin but such is not the case. It is of interest that such a large number failed to respond to the sulfonamides. However, we have no indication that during that treatment they developed any increased resistance to penicillin. This is shown in Table IV.

In 393 cases the lesion was closed, and in 351 it was open when treatment began. Favorable results were obtained in 67.4 per cent of the former and in 61.5 per cent of the latter, not a significant difference.

The relationship between penicillin and surgery in the treatment of these cases is revealed in Table V. It may be surprising to note that so many

cases (258) had no primary surgical procedure while under treatment in this study. Some of these were chronic infections and in the others, surgery was obviated by the use of the drug. In this first group, it is seen that there is a high incidence of excellent results and a sum total of favorable results somewhat better than the average. In the second group penicillin was tried first but did not suffice to control the infection and an operation was later resorted to. The results of the penicillin therapy were considered poor but this is a small group and, therefore, of less significance than the others. In the third group surgery was performed at the same time that

TABLE IV

SHOWING THE RESULTS OF PENICILLIN IN RELATIONSHIP TO PREVIOUS FORMS OF TREATMENT OF SURGICAL INFECTION

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| No previous treatment | 259 | 20.1 | 44.8 | 64.9 | 17.8 | 17.4 | 35.2 |
| Sulfonamides only | 338 | 11.8 | 54.7 | 66.5 | 15.7 | 17.8 | 32.5 |
| Other drugs only | 39 | 25.6 | 41.0 | 66.6 | 20.5 | 12.8 | 33.3 |
| Sulf. and other drugs | 46 | 13.0 | 43.5 | 56.5 | 19.6 | 23.9 | 43.5 |

TABLE V

SHOWING THE RESULTS IN THE CASES WITHOUT SURGERY AND WHEN PENICILLIN PRECEDED, ACCOMPANIED, OR FOLLOWED AFTER A SURGICAL PROCEDURE

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Time Relationship of Penicillin Administration to the Surgical Procedure | Total Number of Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| No surgery | 258 | 22.8 | 43.8 | 66.6 | 14.7 | 18.6 | 33.3 |
| Pen. before surgery | 33 | 9.1 | 30.3 | 39.4 | 21.2 | 39.4 | 60.6 |
| Pen. with surgery | 230 | 11.3 | 59.6 | 70.9 | 18.7 | 10.4 | 29.1 |
| Pen. after surgery | 223 | 9.9 | 49.8 | 59.7 | 19.7 | 20.6 | 40.3 |

penicillin was started and the best results are found in this category. In the last group the penicillin treatment was initiated after the surgery had been done. These groups are not of course strictly comparable. The chief lesson to be learned from the table is that in many cases of surgical infection, surgery may be obviated by penicillin while in others a surgical procedure is required to effect a cure.

The cases have also been divided into three groups according to the method of penicillin administration. The results are shown in Table VI. These three groups are of course not comparable but the table emphasizes the fact that a large proportion of surgical infections may be controlled by the local application of penicillin which represents a very economical method of using the drug.

The question of dosage is an important and a troublesome one. In the

TABLE VI

SHOWING THE RESULTS IN THE THREE GROUPS REPRESENTING THE LOCAL, GENERAL, AND COMBINED METHOD OF GIVING PENICILLIN

| Method of Penicillin Administration | Total Number of Cases | Results in Percentage: Favorable | | | Unfavorable | | |
|---|---|---|---|---|---|---|---|
| | | Excellent | Good | Combined | Questionable | No Effect | Combined |
| General, without local | 438 | 16.7 | 44.7 | 61.4 | 20.0 | 18.5 | 38.5 |
| Local, without general | 142 | 16.2 | 54.2 | 70.4 | 15.5 | 14.1 | 29.6 |
| Both general and local | 164 | 8.5 | 59.8 | 68.3 | 13.4 | 18.3 | 31.7 |

early months of this study the supply of penicillin was greatly limited, the daily dosage was small and it was often stopped as soon as the infection seemed to be under control. Many of these cases had a recurrence of the activity of the infection and required a renewal of treatment. As time went on, more penicillin became available, larger initial doses were given and treatment was prolonged. In many cases large doses were given in conditions where previous experience had shown that small doses would not suffice, or the doses were doubled and doubled again when there was no response to the initial treatment. When a therapeutic agent of low toxicity is available, as with penicillin, the doctor is tempted to use large doses with

TABLE VII

SHOWING THE FAVORABLE RESULTS IN THE CASES ONLY TREATED SYSTEMICALLY, GROUPED ACCORDING TO THE TOTAL AMOUNT OF SYSTEMIC PENICILLIN EMPLOYED

| Total Systemic Dosage | Total Number of Cases | Results in Percentage Favorable: Excellent | Good |
|---|---|---|---|
| Less than 500,000 units | 118 | 30.5 | 31.4 |
| 500,000 to 1 million | 101 | 18.8 | 43.6 |
| 1 to 2 million | 129 | 12.4 | 52.7 |
| Over 2 million | 90 | 2.2 | 52.3 |

TABLE VIII

SHOWING THE FAVORABLE RESULTS IN THE CASES ONLY TREATED LOCALLY, GROUPED ACCORDING TO THE TOTAL AMOUNT OF LOCAL PENICILLIN EMPLOYED

| Total Local Dosage* | Total Number of Cases | Results in Percentage Favorable: Excellent | Good |
|---|---|---|---|
| Less than 10,000 units | 37 | 38.0 | 54.0 |
| 10,000 to 50,000 units | 40 | 15.0 | 55.0 |
| Over 50,000 units | 62 | 4.8 | 53.3 |

* Three cases, exact dosage not recorded.

the idea of having a wide margin above the therapeutic level. Any compilation of dosage figures then, may seem to indicate that the worst results are obtained with the largest doses. A prompt response to an initial dose on the other hand, would permit an early cessation of treatment. Thus, the best results might be associated with the smallest total dosage. Certain

of these points are brought out in Tables VII and VIII. It is noted in Table VII that the excellent or prompt response of systemic treatment decreases as the total dose increases while the good results are in the reverse order. Furthermore, the total favorable results decline sharply over the two million mark.

In Table VIII covering the local treatment, one sees that the same decline in "excellent" responses as the total dosage increases while the "good" responses remain stationary. It is of interest that so many cases responded favorably to simple local treatment with relatively small doses given over a short space of time. This group contains, of course, most of the trivial cases and those in which the infection was well-localized.

Have we any criteria upon which we can base the determination of the necessary or adequate dosage for any given case? It is certainly an individual matter. An "adequate" dose is one that will control the infection and get the patient well. The requirements in any given case depend upon the number and susceptibility of the organisms, the extent and penetrability of the local process, the rapidity of absorption and excretion of the drug and the dosage. An "adequate" dose may range all the way from a few thousand to several million units. The experience of the men working in these study units has indicated that a starting dose of 10,000 units every three hours intramuscularly will be adequate in the average case. The intravenous administration is generally not as acceptable to the patient, is harder to administer from a nursing standpoint and results in more rapid elimination of the drug. In a very sick case a large initial dose of 100,000 units may be given, continuing with 20,000 units every two or three hours. With a plentiful supply of the drug and with the danger of developing resistant strains of organisms by inadequate dosage, so feared by Fleming, it would appear reasonable to start routinely with 20,000 units every three hours and double it once if there is no response in 48 hours. There is very little evidence that larger doses will be any more effective than 320,000 units a day in surgical infections. A single daily dose in oil or wax does not give reliable or consistent blood levels.

If there is a response to the initial dosage which clearly indicates the efficacy of the drug it should be continued at that level until one is certain that the infection has subsided with a margin of safety of five to seven days for systemic treatment or two to three days for local treatment. In certain cases with open wounds or ulcers it may be advisable to continue treatment until the wound has healed or is covered by skin grafts or closed by secondary suture.

The most significant features of the study are revealed when we come to the bacteriologic analysis of the flora of the purulent exudates produced in these established surgical infections. In acute infections it is found that the lesions are usually produced by one species of organism but in chronic infections there is often a mixture of organisms, some causative and other "fellow travelers" which have come into the picture as secondary con-

taminants. In this study it was, therefore, necessary to be prepared to recognize and classify any organism both aerobic and anaerobic, pathogenic or nonpathogenic which might be encountered. It was obvious that if the analyses were to be complete, the classification would have to be carried to species recognition. But for purposes of recording, many of the individual species could be put in larger groups. A code sheet was therefore devised and employed so that the results of the study could be adapted to the punch card system for statistical analysis. A copy of this code sheet for bacterial classification is attached to this report. For purposes of final tabulation this classification has been still further condensed into the following significant groups:

1. The hemolytic streptococci.
2. The coagulase-positive staphylococci.
3. The gram-negative aerobic nonspore-forming rods (including *E. coli, A. aerogenes, Ps. pyocyaneus* and *B. proteus*).
4. *Clostridium welchii.*
5. All other gram-negative aerobic nonspore-forming rods.
6. Micrococci, coagulase test not done.
7. Nonhemolytic streptococci (including the green and indifferent types).
8. All other aerobic cocci.
9. Anaerobic and micro-aerophilic cocci.
10. Aerobic gram-positive rods including the large *B. subtilis* and diphtheroid groups.
11. All other aerobic and anaerobic rods.

In one of the units the hemolytic streptococci were grouped according to the Lancefield classification. Most of the strains fell into Group A, confirming the fact that this is the group of human pathogenicity but a number of strains in other groups clearly demonstrated their activity both in pure and mixed cultures. However, a number of the strains were not grouped and for purposes of this report we have, therefore, put them all together. All of the units have confirmed the importance of the coagulase test as an indication of the pathogenicity of the staphylococci but, again, exceptions were found to this rule. This is more important than hemolysis or the finer classification into *albus, aureus* and *aurantiacus* although most of the pathogenic strains were hemolytic and pigmented.

In any case, it is fair to assume that if any organism is found in pure culture in a purulent exudate that that organism is pathogenic and is the cause of the infection. If it is found in a mixture, it may be pathogenic or nonpathogenic, and it may or may not be taking part in the infection. In evaluating the effect of penicillin on these organisms it is necessary not only to put them to the test in the laboratory to demonstrate whether they are susceptible, indifferent or antagonistic to penicillin, but to note whether they were found in pure or mixed culture in the lesion and whether under treatment they persisted into the second or third week of treatment and whether the infection in which they were found responded favorably or unfavorably to the treatment.

Table IX gives the results for the four principal bacterial groups and it is to be seen at once that all of these groups were found more often in bacterial mixtures than in pure culture, the hemolytic streptococci five times as often, the staphylococci twice as often, the gram-negative rods 19 times as often, while the *Cl. welchii* was found alone only once out of 29 times. The table also shows that the favorable response to treatment occurred much

TABLE IX

SHOWING THE RESULTS OF PENICILLIN TREATMENT ACCORDING TO THE PRINCIPAL BACTERIOLOGIC AGENTS ACTIVE IN SURGICAL INFECTIONS

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| Hemolytic Streptococcus: | | | | | | | |
| Pure | 16 | 12.5 | 56.2 | 68.7 | 12.5 | 18.8 | 31.3 |
| Mixed | 85 | 12.9 | 49.4 | 62.3 | 21.2 | 16.5 | 37.7 |
| Coagulase-positive Staphylococcus: | | | | | | | |
| Pure | 47 | 25.6 | 61.7 | 87.3 | 10.6 | 2.1 | 12.7 |
| Mixed | 98 | 10.2 | 55.2 | 65.4 | 23.4 | 11.2 | 34:6 |
| 4 Principal gram-neg. rods: | | | | | | | |
| Pure | 5 | 0 | 40.0 | 40.0 | 40.0 | 20.0 | 60.0 |
| Mixed | 95 | 1.1 | 49.5 | 50.6 | 25.2 | 24.2 | 49.4 |
| *Cl. welchii:* | | | | | | | |
| Pure | 1 | 0 | 100.0 | 100.0 | 0 | 0 | 0 |
| Mixed | 28 | 7.1 | 35.7 | 42.8 | 32:2 | 25.0 | 57.2 |

more often when the gram-positive organisms were pure than when they were in mixed culture.

*The highest percentage of favorable results are found in the pure staphylococcal infections, and this is perhaps the high point of the study which demonstrates that the organism against which Fleming first demonstrated the activity of penicillin is the one which produces the diseases which respond clinically most satisfactorily to treatment with that drug.*

Among the gram-negative rods the results in the few cases in which they were found in pure culture, were generally unfavorable. It is not clear why two of these cases gave a good response. There may have been other factors at work in these cases, such as the operative procedure or, by chance, these organisms of relatively low pathogenicity may have been inhibited by the doses of penicillin employed. In the bacterial mixtures containing these organisms they may have been relatively unimportant and in these cases at least not capable of real antagonism against the penicillin which was credited with definite benefit. In the single case in which the *Cl. welchii* was found in pure culture, the result was listed as good but in all of the other cases where it was found in mixed cultures, the response was generally bad. This is a confirmation of the results obtained with cases of gas gangrene in the army. While in experimental animals, penicillin was found to be effective against pure cultures of the gas gangrene organisms, in war wounds, so highly contaminated by bacterial mixtures including gram-negative aerobic

rods, did not do as well as had been expected or hoped for. It is probable that the good results occurred in those cases in which there were no organisms capable of producing penicillinase.

With organisms in the other more or less heterogenous groups, shown in Tables X and XI, the results are not striking. In general, aerobic cocci in pure culture are susceptible while the anaerobic cocci and rods are gener-

TABLE X

SHOWING THE RESULTS OF PENICILLIN TREATMENT IN THE PRESENCE OF ORGANISMS OF LESS IMPORTANCE IN SURGICAL INFECTIONS

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| Other gram-neg. aerobic rods: | | | | | | | |
| Pure | 1 | 100.0 | 0 | 100.0 | 0 | 0 | 0 |
| Mixed | 29 | 0 | 37.9 | 37.9 | 37.9 | 24.5 | 62.0 |
| Nonhemolytic strept.: | | | | | | | |
| Pure | 10 | 0 | 70.0 | 70.0 | 30.0 | 0 | 30.0 |
| Mixed | 109 | 8.3 | 43.1 | 51.4 | 28.4 | 20.2 | 48.6 |
| Gram.-pos. aerobic bacilli: | | | | | | | |
| Pure | 1 | 0 | 0 | 0 | 0 | 100.0 | 100.0 |
| Mixed | 102 | 8.8 | 56.9 | 65.8 | 19.6 | 14.7 | 34.3 |
| Staph. coag. test not done: | | | | | | | |
| Pure | 79 | 30.4 | 39.3 | 69.7 | 12.6 | 17.7 | 30.3 |
| Mixed | 80 | 11.2 | 40.0 | 51.2 | 25.0 | 23.8 | 48.8 |

TABLE XI

SHOWING THE RESULTS OF PENICILLIN TREATMENT IN THE PRESENCE OF ORGANISMS OF LESS IMPORTANCE IN SURGICAL INFECTIONS

| | | Results in Percentage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Favorable | | | Unfavorable | | |
| Diagnosis | Total Cases | Excellent | Good | Combined | Questionable | No Effect | Combined |
| All anaerobic and micro-aerophilic cocci: | | | | | | | |
| Pure | 2 | 0 | 50.0 | 50.0 | 50.0 | 0 | 50.0 |
| Mixed | 54 | 7.4 | 50.0 | 57.4 | 24.1 | 18.5 | 42.6 |
| All other aerobic cocci: | | | | | | | |
| Pure | 18 | 5.6 | 61.0 | 66.6 | 5.6 | 27.8 | 33.4 |
| Mixed | 62 | 4.8 | 48.4 | 53.2 | 30.6 | 16.2 | 46.8 |
| All other aerobic and anaerobic rods: | | | | | | | |
| Pure | 2 | 0 | 0 | 0 | 50.0 | 50.0 | 100.0 |
| Mixed | 29 | 0 | 41.4 | 41.4 | 20.7 | 37.9 | 58.6 |
| No Cultures: | | | | | | | |
| Favorable group | 37 | 46.0 | 37.8 | 83.8 | 5.4 | 10.8 | 16.2 |
| Intermediate group | 16 | 6.3 | 68.5 | 74.8 | 18.7 | 12.5 | 31.2 |
| Unfavorable group | 23 | 4.4 | 26.1 | 30.5 | 30.5 | 39.1 | 69.6 |

ally resistant to penicillin and do not respond, but there are often exceptions to this rule.

In 70 cases no cultures were taken before the administration of penicillin. The great majority of those patients presented early infections in the

stage of cellulitis and there was no opportunity to find out what organism was at fault. If these cases are divided up into three groups according to diagnosis to correspond with the series as a whole, as represented in Tables Ia, Ib and Ic, we find that the results run fairly parallel, so that we may assume that the causative organisms in these cases were roughly similar to those in the whole group, but of this we cannot be certain.

A review of the individual records of the cases in which penicillin was reported to have "no effect" permitted a listing of factors which seemed to be responsible for the failure. These are shown in Table XII. Of the 131 cases in this category, 58 were either infected or contaminated with or-

TABLE XII

GIVING A LIST OF PROBABLE CAUSES OF FAILURE OF THE 131 CASES IN WHICH PENICILLIN HAD NO EFFECT

| | | | |
|---|---|---|---|
| 1. The presence in mixed culture of organisms capable of producing penicillinase | | | 58 |
| Including: | | | |
| *E. coli* | 22 | *Aerobacter aerogenes* | 8 |
| *Ps. pyocyanea* | 18 | *Coli* intermediates | 3 |
| *B. subtilis* | 18 | Other gram-negative aerobic rods | 5 |
| *B. proteus* | 15 | | |
| 2. Tuberculosis | | | 6 |
| 3. Tetanus | | | 6 |
| 4. Penicillin-resistant staphylococcus | | | 5 |
| 5. Penicillin-resistant streptococcus | | | 2 |
| 6. Synergism (?) of hemolytic strept. and staph | | | 9 |
| 7. Patient *in extremis* on admission | | | 11 |
| 8. Too little | | | 9 |
| 9. Too late | | | 7 |
| 10. Too conservative surgery | | | 9 |
| 11. Diabetes and arteriosclerosis | | | 7 |
| 12. Metastatic brain abscess, hemiplegia or meningitis | | | 5 |

ganisms which potentially are producers of penicillinase. In many instances the production of penicillinase was demonstrated in the laboratory. Other causes of failure were the presence and activity or organisms not susceptible to penicillin such as tuberculosis, resistant staphylococci and resistant streptococci. Such overwhelming infections like tetanus and metastatic brain abscess, with hemiplegia or meningitis, often killed the patient before the benefit from penicillin could be appreciated. Diabetes and arteriosclerosis seemed to play a rôle by diminishing the blood supply to the infected part. This prevented the entrance of the penicillin into the focus of bacterial activity as well as the nutritive elements necessary for repair. In some cases too conservative surgery which left behind necrotic bone or other tissue handicapped the effective use of penicillin. In a number of cases penicillin was given in desperation when the patient was *in extremis,* and in a few other cases it could be rightly said that it was given "too little and too late." In a small number of cases there was no obvious cause for failure, nine of these yielded on culture a mixture of *hemolytic Streptococcus* and *hemolytic Staphylococcus aureus.* There may be a synergistic action of these two organisms which is difficult for penicillin to combat.

There were 82 cases in the series with septicemia, eight of these had

more than one organism in the blood stream. These cases have been listed according to the diagnosis of the associated surgical lesion and also according to the bacteriology in Tables XIII and XIV. It is seen that good results were obtained in acute osteomyelitis, suppurative arthritis, cellulitis, a furuncle with pneumonia, a carbuncle and a case of rat bite fever. The *hemolytic Streptococcus* had the best score among the bacteria, with 87.5 per cent good results. The *Staphylococcus aureus* yielded a favorable response in 69 per cent. Before the arrival of the sulfonamides the mortality of *hemolytic Streptococcus* septicemia was in the neighborhood of 50 per cent and of staphylococcus septicemia 80 per cent. We have, therefore, come a long way in protection against blood stream infection with these organisms but

TABLE XIII

SHOWING THE RESULTS OF PENICILLIN THERAPY ACCORDING TO THE ASSOCIATED SURGICAL CONDITION IN THE 82 SEPTICEMIA CASES

| | Total Cases | Excellent | Good | Questionable | No Effect |
|---|---|---|---|---|---|
| Acute osteomyelitis | 21 | 6 | 12 | 1 | 2 |
| Chronic osteomyelitis | 6 | 0 | 3 | 0 | 3 |
| Suppurative arthritis | 6 | 2 | 4 | 0 | 0 |
| Cellulitis | 4 | 3 | 1 | 0 | 0 |
| Operative wound infection | 5 | 2 | 2 | 0 | 1 |
| Otitis media | 2 | 1 | 1 | 0 | 0 |
| Thrombophlebitis | 2 | 1 | 1 | 0 | 0 |
| Infected rat bite | 1 | 1 | 0 | 0 | 0 |
| Infected burn | 4 | 0 | 2 | 0 | 2 |
| Furuncles and pneumonia | 1 | 0 | 1 | 0 | 0 |
| Carbuncle | 1 | 0 | 1 | 0 | 0 |
| Empyema | 3 | 0 | 2 | 0 | 1 |
| Deep abscess | 5 | 0 | 2 | 0 | 3 |
| Endocarditis | 4 | 0 | 0 | 0 | 4 |
| Peritonitis and perit. abscess | 4 | 0 | 0 | 2 | 2 |
| Miscellaneous | 13 | 1 | 1 | 3 | 8 |
| | 82 | 17 | 33 | 6 | 26 |

TABLE XIV

SHOWING THE RESULTS OF PENICILLIN THERAPY ACCORDING TO THE BACTERIOLOGY IN THE SEPTICEMIA CASES

| | Total Cases | Excellent | Good | Questionable | No Effect |
|---|---|---|---|---|---|
| Hemolytic streptococcus | 8 | 2 | 5 | 0 | 1 |
| *Staphylococcus aureus* | 45 | 11 | 20 | 2 | 12 |
| *Staphylococcus albus* | 6 | 1 | 2 | 0 | 3 |
| *Micrococcus varians* | 1 | 0 | 1 | 0 | 0 |
| Nonhemolytic streptococcus | 6 | 0 | 3 | 0 | 3 |
| Anaerobic streptococcus | 2 | 0 | 0 | 1 | 1 |
| Pneumococcus III | 1 | 0 | 1 | 0 | 0 |
| Pneumococcus IV | 1 | 0 | 0 | 1 | 0 |
| *E. coli* | 1 | 0 | 0 | 0 | 1 |
| *B. proteus* | 1 | 0 | 0 | 1 | 0 |
| *Streptobacillus moniliformis* | 1 | 1 | 0 | 0 | 0 |
| Unidentified gram-neg. bacillus | 1 | 0 | 0 | 0 | 1 |
| *Staph. aureus* and nonhem. strept. | 5 | 1 | 1 | 0 | 3 |
| *Staph. albus* and nonhem. strept. | 1 | 1 | 0 | 0 | 0 |
| *E. coli* and *B. proteus* | 1 | 0 | 0 | 1 | 0 |
| *E. coli, B. proteus, A. aerogenes, B. subtilis* and *Staph. aureus* | 1 | 0 | 0 | 0 | 1 |
| | 82 | 17 | 33 | 6 | 26 |

our defense is not yet perfect, and when the staphylococcus gets established on the heart valves it is still impossible in most cases to eradicate it. There were no cases, in this series, of recovery after endocarditis had become clinically recognizable.

## SUMMARY

The results may be summarized as follows:

1. Penicillin is effective in controlling the disease either alone or as an aid to surgery in about two-thirds of the general run of established surgical infections.

2. It is most effective in cases of furuncle, cellulitis, mastoiditis, carbuncle, suppurative arthritis, lung abscess, superficial abscess, brain abscess, and osteomyelitis.

3. It is moderately successful in cases of deep abscess, thrombophlebitis, sinusitis, infected soft-part wound, infected operative wound, otitis media, infected compound fracture and ulcer of the skin.

4. It is not so successful in cases of empyema, infected burns, gas gangrene, actinomycosis, gangrene of skin, miscellaneous surgical infections, postoperative pneumonia, peritoneal abscess and diffuse peritonitis.

5. It is more successful in the treatment of acute than of chronic infections and if given early rather than late in the course of the disease.

6. It is often effective when the sulfonamides have failed to control the infection.

7. Many cases of well-localized surgical infection can be successfully treated with local injection of penicillin solution or local application of penicillin in ointment form.

8. "Adequate dosage" (which is defined as that necessary to control the infection) may vary from a few thousand to several million units.

9. Surgical infections are frequently caused by mixtures of organisms.

10. Penicillin is not as successful in mixed infections as in those caused by a pure culture of a susceptible organism.

11. Surgical infections caused by a pure culture of a coagulase-positive staphylococcus yield the best results, responding favorably to penicillin in the great majority of cases.

12. The *Clostridium welchii* (the common bacillus of gas gangrene) is so often found in a mixed culture with other intestinal organisms that clinical cases of gas gangrene often fail to respond to penicillin.

13. An analysis of the cases in which penicillin had no appreciable effect reveals the fact that in a large proportion of the cases, the cultures showed organisms capable of producing penicillinase.

14. Other important causes of failure were:

    a. Resistant strains of staphylococci or streptococci.
    b. Too little or too late administration of penicillin.
    c. Associated tuberculosis or diabetes with arteriosclerosis.
    d. Too conservative surgery.

15. In the septicemia cases, the results were better in those due to the hemolytic streptococcus than in those due to the staphylococcus, probably due to the fact that in the latter type the infection more quickly produces deep metastatic abscesses and vegetations on the heart valves.

Four points warrant special emphasis:

1. Penicillin is a very valuable adjunct to surgery in the treatment of surgical infections and in many instances it can obviate surgery, but it is not a panacea.

2. Penicillin is effective when applied locally to well-localized surgical infections if the organisms are susceptible and not antagonistic.

3. "Adequate dosage" is the amount which will bring the infection under control and get the patient well, and it cannot be determined in any given case before the beginning of treatment.

4. A careful and complete bacteriologic analysis is essential to obtain the best results.

COMMENT.—If the bacteriologic analysis of the surgical infection reveals the presence of organisms which are antagonistic to penicillin, some measure will have to be found to offset their action or else the penicillin will not be permitted to inhibit the associated more important organisms. Fortunately, most of the penicillinase producers are relatively nonpathogenic and are not invasive, so that local application of agents which have been found to interfere with their action, may be sufficient to permit the penicillin to function at the site of the infection, whether it is given systemically or locally. It has been found, in these study units, that parachlorophenol in a dosage of .25 of 1 per cent, 9-aminoacridine in a concentration of 1:1000, 5-nitro-2-furaldehyde-semicarbazone in a dilution of 1:1000 and streptothrycin and streptomycin in a concentration of 500–5,000 units per cc. may be successfully employed.

If the resistant or antagonistic organisms are invasive, some agent must be found which will perform this function when used systemically. At present, streptomycin is the only one that we know of that can be used systemically, and is just beginning to be available. There is some hope that new antibiotics will be found which will not have the handicap of inactivation by associated resistant organisms.

Bacitracin, which was discovered in the author's laboratory and is now being developed by a number of commercial firms, is not inhibited by these gram-negative bacteria, although it is not potent against them. It is not yet available in a form suitable for human systemic injection. The author believes that the ultimate control of such mixed infections will come when we can find some chemotherapeutic or antibiotic agent which will destroy or inhibit these second-rate organisms and which can be combined with penicillin for either systemic or local application. These facts are presented with the hope that they may clarify some of the points in the use of penicillin so that it may be more successful in your hands than it has been heretofore.

DISCUSSION.—DR. ALLEN O. WHIPPLE, New York City: I rise to remind the members of the Association of the time when Doctor Meleney was first assigned the difficult task of evaluating the effect of the "wonder" drugs, the sulfonamides, in the healing of wounds. The conditions under which that study was carried out were difficult, because there was a tremendous enthusiasm at that time for the local use of sulfonamides, and when his reports began to appear there was a great deal of bitter criticism and even accusation that the morale of the Army was being disturbed. But it is interesting that, as time has gone on, from various war areas the results which he reported then have been corroborated. And I wish to commend Doctor Meleney for the meticulous care he has used and the fair judgment he has at all times attempted to use in evaluating the effects of these newer chemotherapeutic agents in preventing local wound infection.

DR. JOHN S. LOCKWOOD, New Haven, Conn.: In supplementing what Doctor Whipple has just said, I might remind this Association that just three years ago it was implied by a discusser of Doctor Meleney's paper on wound prophylaxis that those who had participated in the program designed to evaluate the effect of the sulfonamides in wound infection, within five years, would repudiate the preliminary conclusions which Doctor Meleney presented at that time. As a matter of fact, there is now a very general recognition of the limitations in the usefulness of chemotherapy in preventing infections in accidental wounds, and military experience has confirmed the civilian work.

In amplification of Doctor Meleney's interesting report, I would like to suggest that penicillin has stood out as being conspicuously useful in those types of infection characterized by actual tissue invasion by penicillin-susceptible organisms. In types of infection where the infection is more saprophytic in character, penicillin has not been of particularly great value. The infections Doctor Meleney described as being unresponsive to penicillin may have been unresponsive because the organisms are, or have become, penicillin-resistant. But I think it is well to keep in mind the fact that many of the infections in which penicillin was of no value were in wounds of fairly long duration, in which conditions had become ripe for invasion by saprophytic organisms, among them many gram-negative varieties. The lack of effect of penicillin may have been due directly to the resistance of these bacteria but, on the other hand, the poor results may have been inherent in the physiologic character of the wounds. Certainly, the treatment of infections in which penicillin-resistant organisms predominate would seem to be surgical rather than chemotherapeutic. In most of the infections in which one cannot demonstrate the effect of penicillin it is time to undertake surgical revision and skin grafting procedures which, even in the face of superficial infection, can be carried out.

It has been a cause of recent concern to the Committee on Chemotherapy of the National Research Council that penicillin is not a single chemical compound; it is at least four different penicillins known as G, F, X, and K, each with a different chemical constitution. They all possess a strong effect against similar varieties of organisms *in vitro,* and all meet the ordinary methods of bio-assay used in testing. However, penicillin K is a very unsatisfactory penicillin from a chemotherapeutic standpoint. It is rapidly broken down in the body; it is all gone within 30 minutes. This is of some practical importance, because it is thought that a good deal of the penicillin distributed has contained as much as 60 per cent penicillin K, and there is reason to believe that some of the spotty clinical results have been due to penicillin K in commercial penicillin. This has been called to the attention of the manufacturers, and the problem will now be remedied, but for six months to a year there has been a good deal of penicillin K in circulation. This provides a basis for explaining some of the discrepancies in results in penicillin treatment. We hope it will in the future contain 80 to 90 per cent penicillin G, or other penicillin of known value, so that penicillin K may be eliminated as a possible source of poor results.

DR. JONATHAN E. RHOADS, Philadelphia, Pa.: I wish to congratulate Doctor Meleney on assembling this very complex group of data and presenting them so concisely. It is somewhat surprising that the poorest results in the entire series were observed in spreading peritonitis. We did not have very much confidence in the drug in treating peritonitis so we did not at first include these cases in the clinical study carried on in Philadelphia. However, certain animal experiments were undertaken. Dr. John Murphy, Dr. Robert Ravdin and Dr. Harold Zintel produced experimental peritonitis in dogs by the method of Poth. In a small series they obtained a 70 per cent survival when penicillin was administered.

Miss Ann Nichols in our laboratory has obtained some evidence that in mixed infections, of which peritonitis is an example, you may get a synergistic effect between penicillin and streptomycin. Since some organisms are susceptible to one and some to the other, it is not surprising that mixed cultures may be inhibited more effectively by small amounts of each drug than by either one alone.

In another series of animals studied by Doctor Zintel, and his associates, in which peritonitis was produced by ligating the appendix and its mesentery, the combination of penicillin and sulfonamides resulted in a slightly lower mortality than did streptomycin alone. Experiments are now in progress combining streptomycin with the other drugs, and the mortality is running at a still lower rate.

Again I want to thank Doctor Meleney for putting these data in so useful a form.

DR. FRANK L. MELENEY, New York City (closing): Time did not permit me to pay adequate tribute to those who contributed to this study. I would like to mention besides Drs. Harold Harvey and Robert Elliott, Drs. John Lockwood, William White and Jonathan Rhoads, in Philadelphia, William Altemaier, in Cincinnati, John Hirshfeld, Roy McClure and Conrad Lam, in Detroit, and Alton Ochsner and Guy Caldwell, in New Orleans, all of whom contributed largely to this work by sending in their case records. From these we have derived our data. I am glad that Doctor Lockwood emphasized the possibility of other factors operating, when penicillin has failed. All these factors have been mentioned, but in going over these cases with great care there was a large number (58) in which the cause of failure seemed to be the presence of those organisms which are capable of producing penicillinase. When such surgical infections are under treatment there should first be a careful bacteriologic analysis of the wound. Then each and every strain of organism should be tested both for susceptibility and for antagonism to penicillin. If antagonistic species are found some measure must be found to inhibit their activity. Most of the penicillinase-producing species are nonpathogenic, so that local agents which interfere with their growth may be sufficient to permit penicillin to function against susceptible pathogens at the site of infection. We have found that 1-400 parachlorophenol is one of the most potent antibacterial agents against these penicillinase-producing gram-negative bacteria, and in that concentration it is not toxic when applied locally. Streptothyrcin and streptomycin in concentration of 500-5,000 units per cc. may be employed locally if the organisms are susceptible to them. At present, streptomycin is the only one of the potent antibacterial agents that can be used systemically, and that is sometimes toxic. It is hoped that new antibiotics will be found that will not be inhibited by either injured tissue or bacteria, the chief inhibitors of the sulfonamides and penicillin, respectively. Such a chemotherapeutic or antibiotic agent might then be combined with penicillin to render it more effective in the treatment of established surgical infections due to a mixture of organisms. Bacitracin may fall into this category.

# THE CLINICIANS' RESPONSIBILITY IN THE TEACHING OF SURGERY*

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THE METHODS of teaching medicine are ever changing and have been as far back as the history of medical education goes. No other subject of American education has been so drastically reformed in so short a time.

From a surgical standpoint scientific medicine began with the science of *anatomy* sponsored by Vesalius. Then with the advent of Harvey the science of *physiology* was added, and led by Morgagni, *pathology* was added. Soon there developed from anatomy, *histology* and *embryology*, from physiology, *biochemistry*, and from pathology, *bacteriology*. Thus, we see how it has been necessary with the great amount of increasing knowledge in front of the student, for the plan of teaching as well as the type of teachers, to change.

Clinicians in the past were the teachers of the fundamental subjects and medical students, therefore, had the subjects presented to them with their clinical application always before them. On the other hand, busy clinicians could give little effort to research and the development of the true science of these subjects. A change was inevitable and the medical schools were the natural institutions for this effort. Thus, the result was that the research teacher gradually replaced the clinical teacher. To medical faculties were added scientists who were specially trained in the true science of medicine.

During the past 25 years the clinical teachers have been gradually replaced by the pure science teachers and the once close association between the clinical and fundamentals has gradually grown wider, and, as stated by Cropper: "It would seem that the medical schools should steadfastly set their faces against their preclinical teaching, remaining solely in the hands of the pure scientists. Pure scientists in any branch of the subjects tend to demand from the student a far too detailed knowledge of the branch."

Also, it may be true that the standards of medical education and the accepted curricula of medical schools by committees on medical education are largely the results of the opinions of teachers of fundamental subjects rather than the clinicians. This situation is quite different from that in the beginning (1904) when the Council on Medical Education of the American Medical Association started to function under the able leadership of the distinguished clinical teacher of surgery, Dr. Arthur Dean Bevan.

It has seemed wise and perfectly natural with the advance of the many full-time preclinical science teachers, that from this group deans and other

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administrative officers of medical schools should be selected. Though the membership of the Association of American Medical Colleges includes all members of medical faculties, it is the administrative officers of the medical schools who actually carry on the good work of the organization. We must admit the tremendous value to medical education of this organization, but is it not possible the criticism we may have of the modern undergraduate teaching may be attributed to the difference in viewpoint of the teachers of the fundamental subjects and that of the teachers of the clinical subjects? No one can deny that, in general, scientific advancement which is for the good of the patient has been due to our modern methods of teaching, but this does not prevent us from finding fault with the system. It may be that scientific advancement is carried on in some respects at the expense of the best interest of the graduate in medicine.

No article in regard to medical education should be complete without a reference to a brilliant contribution by a great clinical teacher — Dr. David Cheever, read before the American Surgical Association, in 1933, under the title of "Anatomy Eclipsed," who says: "If the systematic instruction is given by a professor who has no clinical experience, who knows only from hearsay — if at all — and is not concerned with the reasons why anatomical facts are of importance to the practicing physician or surgeon; whose real interest and enthusiasm lie in the field of comparative morphology or experimental embryology, it can scarcely be expected that the subject shall be presented in a stimulating, interesting and profitable manner. It is unwarrantable to assume that junior instructors, teaching in sections, ill-paid and lacking in experience as teachers, will assure the entire class of receiving what they ought to get from a senior member of the department."

Dr. Cheever states further: "The teaching of anatomy is under the direction of the laboratory assistants generally, who hold no degree in medicine and have no clinical experience. Doctors of Philosophy, Bachelors of Science to a considerable extent are responsible for the teaching of fundamental subjects in the American medical schools."

Dr. Harvey Cushing, the famous clinical teacher, has stated: "More and more the preclinical chairs in most of our schools have become occupied by men whose scientific interest may be quite unrelated to anything that obviously has to do with Medicine, some of whom, indeed, confess to a feeling that by engaging in problems that have an evident bearing on the healing art they lose caste among their fellows." "It tends to create a sense of frustration in the morphologic and clinical anatomist to learn from the pen of the Professor of Anatomy in one of our most conspicuous and richly endowed schools that the subject of the former's study and teaching is nothing but "fixed protoplasm," that "Human anatomy was in great danger of becoming nothing more than a handmaid to Medicine and Surgery" — and that "the days when the anatomist commanded the respect and confidence of his medical colleagues solely on the basis of his knowledge of static morphology, are rapidly disappearing."

Quoting again from Dr. Cheever: "It is unreasonable to declare that gross descriptive morphologic anatomy is unworthy of being taught by a man of seniority and experience in teaching, of wide clinical experience, preferably in surgery, and of broad interests in the whole field of medicine, especially the fundamental subjects." "Let us believe that the prime duty of the medical school is to prepare men to practice the art of preventing and healing disease and let us consider that duty as out-ranked in dignity and importance to no other on earth."*

Standardizing committees realizing this deficiency have endeavored to compensate by recommending correlating lectures for the first and second year classes by members of the clinical staff upon the subjects of anatomy, physiology, biochemistry, *etc.* These lectures are irregular, not systematic and serve only as entertainment for the student, I am afraid, and fall far short of the objective which they are expected to reach.

In the institution with which I have been connected for the past 35 years (the University of Texas), surgical teaching began following closely the British schools, in which the fundamentals of anatomy, pathology and physiology were the attracting center, which were ever emphasized in the fundamentals of surgery.

The present curricula of surgical teaching in the modern medical school has tended to draw away from these basic subjects and we have had considerable misgiving in giving our consent to the giving up of many hours of instruction in them. This situation has been more difficult for us to accept because of the previous facts which we have endeavored to bring out showing that the clinical teachers no longer have a part in the teaching of these fundamental branches, which has naturally resulted in the student coming to his junior year without having had the clinical viewpoint to show him the use to which the fundamental knowledge may be used in clinical work for the good of the patient. Because of this state of affairs we have felt more and more that the surgical departments should spend considerable time in teaching applied physiology, applied or surgical anatomy,† and surgical pathology. Our former extensive course in surgical anatomy has been reduced greatly but is still taught in the senior year. Time allotted to classes in surgical pathology has been greatly reduced but we have been able to retain some 32 hours per student in the senior year, and physiology, which we have attempted to teach with experimental or animal surgery, is given in the junior year occupying some 22 hours.

Believing very strongly that a weakness exists in present teaching methods, and also knowing the unpopularity of the above subjects with standardizing committees on curricula of the American Medical Association and the Association of American Medical Colleges, we have endeavored to secure the opinion of the teachers of surgery from medical schools in America

* Though the teachers of anatomy in our school are Ph.D.'s they are high in rank and do the direct teaching of the subjects.

† Thirty hours have been allowed for this year.

in appraising these problems. Replies to a letter requesting opinions were received from 60 professors from 40 medical schools of the United States and Canada. Those who replied showed the same discontent in regard to their present methods of teaching and uncertainty as to the teaching schedules which should be maintained.

### SURGICAL ANATOMY

Thirty-five of the 40 medical schools continue teaching surgical anatomy. Five had discontinued the teaching of surgical anatomy. The number of hours given to surgical anatomy varied from 20 hours to 50 hours, and the great majority expressed strong convictions that surgical anatomy should have a place in the undergraduate medical school curricula and be taught by highly experienced and trained surgeons.

Dr. I. A. Bigger, of the Medical College of Virginia, says: "We had to give up for the time-being our course in surgical anatomy. I am extremely sorry this had to be done and we do plan to again develop such a course when we have an adequate staff."

Dr. Warren H. Cole, of the University of Illinois, states: "We devoted 48 hours total to surgical anatomy. I am personally convinced that we should not abandon our course in surgical anatomy, even though the student is not going to be a surgeon. He forgets so much anatomy that the course in his junior or senior year, which would correlate anatomy with a surgical approach, should be a method of making the dry facts stick a little better in the student's memory."

Dr. Loyal Davis, of Northwestern University, says: "We give a class in surgical anatomy to the senior medical students. They are given cadavers to dissect. The class is taught by a surgeon who has, in the past, demonstrated his ability to teach gross anatomy and a man who is much interested in his class. It is given to about 40 students for four hours a week for one quarter, that is, 12 weeks."

Dr. J. Stewart Rodman, Woman's Medical College of Philadelphia, says: "I am glad to learn that you are holding on to surgical anatomy and are giving it to your senior students in a course lasting from 18 to 20 hours to one-third of the class at a time. I believe that surgical anatomy should be taught by surgeons and not by the Anatomic Department. We have followed this plan with success in our own teaching."

Dr. Alfred Blalock, of Johns Hopkins Hospital, says: "I feel very strongly that surgical anatomy is well worth while."

Dr. Dan Elkins, of Emory University, says: "I have long been of the opinion that so much extraneous matter is slipping into the curriculum that our students are graduating with a poor basic and fundamental medical background. I sometimes think it would be better if we went back to the old system where anatomy was taught by surgeons. No undergraduate medical student can master all of anatomy, but a good anatomist who is also a good

surgeon can stress the importance of certain anatomic structures and relationships, a thing which is not done by the so-called pure anatomist."

Dr. Frederick A. Coller, of the University of Michigan, says: "We give 22 practical regional studies on a cadaver, and each laboratory period is preceded by a demonstration stressing the surgical aspects of the region under consideration. Although it is an elective course, 90 per cent of the students take it."

Dr. Edwin P. Lehman, of the University of Virginia, says: "We give a rather extensive course in surgical anatomy. The value of this course is to me very great. The record of Virginia students in state board examinations in anatomy has been greatly improved since this course was initiated. It is my conviction that anatomy learned after clinical contact is going to be retained much better than anatomy learned as a pure science."

Dr. Allen O. Whipple, of Columbia University College of Physicians and Surgeons, says: "We have experienced the curtailment in our medical school curriculum of the teaching hours in anatomy and pathology, but both these basic subjects are essential to the teaching of surgery. We also give a course in regional anatomy to our third year surgical clerks, covering the neck, the extremities, the chest and abdomen. I have conducted the exercises in the abdomen for a number of years. In this course we emphasize the surgical significance of anatomic structure, but we do not use the course to teach surgical technic."

Dr. John Morton, of the University of Rochester School of Medicine and Dentistry, says: "We give a course in surgical anatomy in the senior year, also give correlation courses to the first-year students. In the first year we give clinics illustrating the importance of anatomy. This is to demonstrate to the students some of the reasons why they study the muscle origins, insertions, *etc.* We present such things as poliomyelitis, paralysis, nerve injuries, congenital defects, *etc.* This exercise occurs once a week during their anatomic course. At the end of the second year we teach physical diagnosis along with the medical people, but we teach it from a surgical standpoint. That includes methods of diagnosis of ear, nose and throat, neck, thyroid, and the breast which they do not get on medicine, orthopedic examinations for joints, spine and feet, urologic and rectal. All these methods of examination are taught by the surgical department, also a complete neurologic examination and blood vessels."

Dr. Alton Ochsner, of Tulane University, says: "I think it has been perfectly all right to reduce the number of hours given to anatomy, since the older curricula were top-heavy with anatomy. On the other hand, I think it is desirable to give some anatomy in the clinical years. We give a course in surgical anatomy, which is probably not as elaborate as yours. It consists of demonstrations, on presected bodies, of regional anatomy. This is given by members of the surgical staff once a week to a third of the class at a time, for a period of one-third of the year and is given in the Junior year. I believe that the students get a great deal out of it, and it is also valuable to

the staff since it gives them a chance to review their anatomy by presecting the bodies."

Dr. Owen H. Wangensteen, of the University of Minnesota, says: "It would be a good plan to reduce the number of hours in preclinical years, bringing the student into the clinical years at an earlier date; then, to give the students in the third and fourth years additional training in anatomy and pathology. I think this is sound. The anatomists obviously do a good job in absorbing the difficult shock of initiating the medical students into the discipline of hard study. I think it would be sound to return to the plan as stated above. We do give a course called "Applied Surgical Anatomy" and I think they get a good deal of good out of it."

Dr. Dallas B. Phemister, of the University of Chicago, states: "I am in favor of a course in surgical anatomy for seniors. This course consists of lecture demonstration of the surgical anatomy of a field followed by student operations of the cadaver. Though it is elective the success of the course is inferred by the fact that at least four-fifths of the class take it and I think it is worth while."

Dr. Erwin R. Schmidt, of the University of Wisconsin, says: "I am afraid that I am still a little old fashioned and believe that surgeons have to be thoroughly grounded in surgical anatomy, pathology and dog surgery. These things to me are fundamental principles upon which a surgeon must build. I feel the way you do — that I do not want to become inflexible and not accept new methods; but I have reached the stage that after these things are taken care of; namely, surgical anatomy, surgical pathology and dog surgery, then I am open-minded, and I would be very loath to change my ideas."

Dr. Thomas G. Orr, of the University of Kansas School of Medicine, says: "I am much interested in the teaching of surgical anatomy. After all the criticism of the teaching of anatomy by anatomy instructors which has appeared in the literature, I am still of the opinion that they do a very good job. The teaching of anatomy as applied to clinical medicine, is in my opinion, strictly a responsibility of the clinicians, preferably in the senior year. The modern clinician should be able to emphasize in his teaching anatomy, pathology, physiology and biochemistry. At present we have only one short course of 12 weeks in surgical anatomy. This is hardly enough but it is the best we can do with our crowded curriculum. Teaching in medical schools seems to be a very popular subject for discussion at present. Some of the discussions appeared to me to be rather visionary, particularly those which placed so much emphasis upon the correlation of the preclinical subjects with clinical subjects. It is my firm belief that preclinical laboratory men are usually not competent to teach correlation courses, and here again such teaching must be largely delegated to up-to-date clinicians. I believe some of our younger men may be more competent to emphasize such subjects as physiology and biochemistry than our older men."

Dr. David Cheever, of the Peter Bent Brigham Hospital, Boston, says:

"I think you would be interested in an article of mine entitled "Anatomy Eclipsed" in the ANNALS OF SURGERY for October, 1933, and contained also in the transactions of the American Surgical Association for that year. I have not changed my opinions then expressed, and will only repeat that I think it is most unfortunate that the teaching of gross anatomy is largely turned over to Ph.D.'s and other persons who have no knowledge of surgery or medicine. Please read it."

Dr. W. D. Gatch, of the Indiana University Medical Center, states: "I regard your plan of teaching surgery as essentially sound. I believe that teaching should be built around anatomy, pathology and applied physiology."

### SURGICAL PATHOLOGY

In reply to the question of the value of the teaching of surgical pathology, the answers were almost 100 per cent in the affirmative. Many of these replies were to the effect that surgical pathology should be taught in the Department of Surgery — again, in order that the student might get the clinical viewpoint and correlation of the pathologic picture with the clinical. In fact, it occurs to us that the strongest surgical departments with which we are acquainted, lay great stress upon this arrangement.

Dr. Evarts Graham, of Washington University School of Medicine, says: "I have had the conviction for a good many years that the emphasis in the surgical teaching of undergraduate students should be placed largely in the diagnosis of surgical conditions, the teaching of what can be accomplished by surgery in various disorders, the principles of postoperative care and all of those things which go to make up the complicated picture of disturbed physiology in connection with surgical disorders and a *great deal of emphasis on surgical pathology. Here the Department of Surgery gives all the instruction in surgical pathology.* I believe it is a good thing to emphasize in the student's minds the fact that no one can be a really good surgeon unless he is a good pathologist. The fact that we do stress pathology so much here has its effect on all of the young men who are taking graduate work in surgery."

Dr. J. Stewart Rodman says: "From my experience with the American Board of Surgery I would say that there can be no more sound approach to surgery than through anatomy and pathology. These are the only two basic sciences in which a special examination is given."

Colonel Daniel C. Elkins, of Emory University, says: "I have been particularly impressed since I have been in the army with the lack of knowledge of anatomy and pathology on the part of recent medical graduates. We have had three or four groups of some 30 men who have been sent here for three months training. They come from all schools in the country, and very few of them have a basic conception of what these subjects mean in relation to clinical practice. Day in and day out we have to expose large vessels and large peripheral nerves, and their ignorance concerning these matters is appalling. The board members of the American Board of Surgery

were so impressed with the lack of knowledge of anatomy and pathology that one of its members — Dr. Allen O. Whipple — was induced to address the Association of American Medical Colleges on this subject. I am afraid he did not get very far."

Dr. J. Deryl Hart, of Duke University, says: "It has been a source of considerable concern to me that we have not had a course in surgical pathology. Our surgical pathology is handled by the Pathologic Staff, and they have not felt they were in a position to offer such a course. After the war we plan to have a surgical pathologist who will be jointly responsible to Surgery and Pathology, and he will have a course in surgical pathology."

Dr. Erwin R. Schmidt, of the University of Wisconsin, says: "We give 32 hours of surgical pathology to junior students; in addition, in the senior year, surgical pathology is taught throughout the year in a surgical pathologic conference which is held once a week."

### ANIMAL OR EXPERIMENTAL SURGERY

Sixteen of the 40 schools have classes in animal surgery. In regard to the teaching of animal surgery, the answers indicate that about one-half of the schools conduct such classes and about one-half do not. The expressed opinions vary considerably in regard to the value of such teaching. There was rather universal opposition to teaching surgery in the strictest sense on animals. Those who favored such a class emphasize that its value was to teach asepsis, tissue handling and hemostasis, as well as demonstrating physiologic principles, or a correlation course in physiology conducted upon animals. Many were outspoken in opposition to such classes, others were favorable.

Dr. Barney Brooks, of Vanderbilt University, states: "As to animal surgery, we formerly had a required course (one year) one afternoon each week for all the students in the third year class. I must confess that although the students always expressed a very great amount of enthusiasm for this course in animal surgery, I had a considerable amount of question in my mind as to whether it was worth while or not. At least about five years ago we changed the course to an elective course, but I believe nearly all the students elected to take it. During the past three years the course has been discontinued entirely, not only because of the shortage of our teaching staff, but also because of the shortage of animals and because of our inability to obtain janitors for the preparation of the materials used."

Dr. Loyal Davis states: "We discontinued a class in animal surgery because we felt it was a waste of animals and the men learned nothing, but even more important, we believe that surgical technic should not be taught until the man goes into the hospital as a clinical clerk or intern. We teach them aseptic technic when they are clinical clerks and each one of the senior students has a clerkship in surgery."

Dr. Evarts Graham states: "We gave up our course in dog surgery five or six years ago. I think it has some value in teaching the importance of

asepsis and the gentle handling of tissues but yet I think it has also certain very great disadvantages. I could not help feeling that the course had two results which were harmful. One was that it overemphasized the technic of operative surgery and, in the second place, that it gave the students the idea that surgery is much easier than actually it is. The ease with which almost any operation can be carried out on a normal dog is so different from that experienced on the human being with marked local pathologic changes, together with the fact that the patient may be a poor risk anyway, created a false impression that the removal of a gallbladder, the resection of a stomach, or a thyroidectomy, was a very simple procedure. However, the giving of the course is such a big job that I seriously question whether it is worth the labor put into it, aside from the actual harm that it may do."

Dr. Frederick A. Coller says: "We also give a course in the surgical laboratory to work on animals. With us this is given in the senior year and we likewise give it to stress the handling of tissues, aseptic technic and to some degree anesthesia. We make no attempt to teach them in any detail the various operations of surgery at that time."

Dr. Howard C. Naffziger states: "As to animal surgery, we would prefer to give it in the third year, but because our students are not at the University of California Hospital during that year, we give it in the fourth, and I imagine give the same sort of course that you do. They receive instruction in anesthesia, the duties of a scrub nurse, methods of cleaning up, wound healing and the use of the different kind of sutures, *etc.*"

DISCUSSION.—From the foregoing information we can correctly state that it is the opinion of the clinical teachers of surgery in America that the curricula of medical schools should require:

1. *Surgical Anatomy:* The teaching of surgical anatomy by clinical surgeons during the junior, or preferably the senior year of medical school. This teaching should be done when possible by those of higher rank and experience in the surgical departments. The number of hours devoted to this teaching should be not less than 20, and preferably 40.
2. *Surgical Pathology:* Surgical pathology should be reviewed and greatly emphasized in the senior year. Gross and microscopic pathology, particularly that of neoplasms, should be given 40 to 50 hours. These subjects should be taught by well-trained pathologists jointly with the clinical teachers of surgery.
3. *Animal Surgery:* The teaching of applied physiology in the animal laboratory work, though not essential in the undergraduate curricula, may be advisable. The principles and practice of aseptic technic may be taught to advantage. This work probably should be given in the junior year and before the student enters the operating room. Aseptic technic may be learned, as well as the methods of handling tissue, ligating vessels and the use of sutures. Also, it may be that some of the students becoming familiar with the management of animals and

laboratory technic, will be encouraged to do research work in the future. The combining of the teaching of anesthesia with surgery in the animal laboratory gives an opportunity for demonstrating the physiology of respiration, fundamental principles of open chest operations, as well as a greater knowledge of anesthesia in its physiologic application.

*Finally,* it is the duty of the clinical teachers of surgery to take more interest in the work being done by the Association of American Medical Colleges and the Committee on Medical Education and Hospitals of the American Medical Association. Attendance upon the meetings of these organizations and expressing opinions in regard to undergraduate teaching would be welcomed by the accrediting bodies and would result in a teaching program more acceptable to clinical teachers, as well as those of the fundamental subjects.

## REFERENCES

[1] Cropper, C. F. J.: Preclinical Years: With Special Reference to Teaching of Physiology, British Medical Journal, 1, 389, March 27, 1943.

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## ANNOUNCEMENT

DR. ALLEN O. WHIPPLE, Valentine Mott Professor of Surgery at Columbia University and Director, Surgical Service, Presbyterian Hospital, has accepted a position on the medical faculty of the American University of Beirut.

Announcement of Doctor Whipple's plans was made by Albert W. Staub, American Director of the Near East College Association. Doctor Whipple, who retires September 30th this year, after 35 years on the Columbia Medical faculty and 34 years at the Presbyterian Hospital, will leave for Beirut, Lebanon, late in September.

"Doctor Whipple, one of America's great surgeons, will advise on the development of the new medical center of the American University of Beirut," Mr. Staub said. "As a trustee of the university he has helped plan the new teaching hospital at Beirut, one of the pioneer medical centers in the Near East where more than one thousand doctors have been graduated since 1867."

Doctor Whipple, a graduate of Princeton and Columbia, has specialized on surgery of the pancreas and spleen. During the war he was chairman of the subcommittee on infected wounds and burns of the National Research Council, Fellow of the American Academy of Surgeons, editor and author of medical treatises and books, and officer of several medical and surgical organizations.

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# RADICAL SURGERY FOR CERTAIN CASES OF PANCREATIC FIBROSIS ASSOCIATED WITH CALCAREOUS DEPOSITS*

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PRESENT-DAY ADJUVANTS to the surgeons' armamentarium in the preoperative, operative, and postoperative periods have made radical operations feasible which ten years ago were considered impossible. In certain fields, such as in primary cancer surgery, these extensive procedures are justified where the wide removal of possible cancer-bearing tissue insures a more certain arrest of the tumor. Or, where with a hazardous operation, technically difficult, a readjustment of the circulation by vascular anastomosis corrects a hopelessly deranged physiology.

The pancreas is one of the organs which in recent years has been dealt with radically in an attempt to cure otherwise hopeless disease and in the past three years total pancreatectomy has been successfully accomplished with surprising results in some instances. Priestley[1] was the first surgeon to achieve this success in a patient with severe hypoglycemia after a thorough exploration of the organ had failed to reveal an islet cell tumor. This patient is cured of her hypoglycemia 36 months after operation, and does not require as much insulin as many a diabetic. To date, 14 total pancreatectomies have been performed, and are recorded in Table I.

The first successful total pancreatectomy for chronic pancreatitis associated with extensive calcareous deposits was performed by Claggett[2] in November, 1944. This patient was relieved of her unbearable pain. Ten weeks later, while in her home, she developed a severe hypoglycemic reaction which was not recognized, resulting in death. Her diabetes was controlled by a daily dose of eight units of protamin-zinc insulin and 30 units of regular insulin taken in one injection in the morning.

We wish to record two of these total pancreatectomies and three other radical procedures with removal of a large part of the organ for intolerable pain associated with pancreatic fibrosis and calcareous deposits and pancreatic calculi (Table II).

*Read before the American Surgical Association, April 2-4, 1946, Hot Springs, Virginia.

We do not intend to review the subject of pancreatic lithiasis in this paper. The subject has been recently summarized in papers by King and Waghelstein[3] in 1942 and by Lionello, Ficcara and Ryan[4] in 1944. But we wish to emphasize certain points in the indications for radical resection of the pancreas for this condition.

Extensive calcification of the parenchyma of the organ is rare as compared to the finding of numerous calculi in the ducts. Fibrosis of a part of the organ is frequently associated with either calcification or calculi. Cystic degeneration or dilatation of the obstructed ducts is usually present. Disturbed carbohydrate metabolism in the form of mild diabetes is found in about a third of the cases. The same is true of abnormal fat digestion and

TABLE I

CASES OF TOTAL PANCREATECTOMY PREVIOUSLY REPORTED AND INCLUDING TWO CASES BY THE AUTHOR

| Author | Age | Sex | Diagnosis | Survival After Operation | Approximate Insulin Daily Dosage | |
|---|---|---|---|---|---|---|
| 1. Rockey[5], 1943 | 51 | M | Carcinoma pancreas | 15 days—died | 27 units | |
| 2. Goldner and Clark[6], 1944 Case of Brunschwig | | | Carcinoma pancreas | 11 days—died | 20 units | |
| 3. Goldner and Clark[6], 1944 Case of Clark | 45 | M | Carcinoma bile duct | 10 days—died | 40 units | |
| 4. McClure[7], 1944 (Case of Fallis) | 46 | M | Carcinoma pancreas | Alive 9 mos. after operation | 26–34 units | |
| 5. Brunschwig, *et al*,[8] 1945 | 53 | M | Carcinoma pancreas | Died 3.5 months after operation | 40 units | |
| 6. Priestley,[1] 1942 | 49 | F | Islet cell adenoma | Well after 3 years | 18–25 units | |
| 7. Waugh,[2] 1944 | 36 | F | Islet cell adenoma | Well 8 mos. after operation | 32 units | |
| 8. Dixon,[2] 1944 | 50 | M | Carcinoma of pancreas | 15 mos. after operation showed recurrent abdominal mass, anemia and jaundice | 40 units | |
| 9. Claggett,[2] Nov. 1944 | 37 | F | Chronic pancreatitis with calcification | 2.5 mos. after operation died in an hypoglycemic attack | 38 units | |
| 10. Zinninger[9], 1945 | 39 | M | Chronic pancreatitis with pancreatic-lithiasis | Died after operation 30 hours | 30–50 units | |
| 11. Brunschwig,[10] 1944 | 67 | M | Carcinoma pancreas | 3 days—died | | |
| 12. Brunschwig,[11] 1946 | | | Carcinoma pancreas | 14 days—died | | |
| 13. Whipple, 1945 | 26 | F | Pancreatic calculi | 12 mos. Relieved of pain | 30–80 units | Included in Table II of this paper |
| 14. Whipple, 1945 | 46 | F | Pancreatic calculi | 7 days—died | 20–40 units | Included in Table II of this paper |

abnormal stools. Mild pain in the epigastrium or a sense of nagging epigastric distress is present in the majority of the patients. It may appear intermittently with periods of complete freedom or it may be fairly constant. In some patients, however, and not corresponding necessarily with the extent of calcareous deposits in the pancreas, the pain is so severe and constant, frequently radiating through to the back, as to be intolerable and morphinism is a serious threat. A history of a previous acute pancreatitis or of chronic alcoholism is common. The most important laboratory examination is a plain film of the upper abdomen to demonstrate the presence and extent of the calcareous deposits which may appear in the head, the body,

TABLE II

RADICAL RESECTIONS OF THE PANCREAS, BY THE AUTHOR, FOR PANCREATIC LITHIASIS

| Unit No. | Sex | Age | Duration of Severe Epigastric Pain | Previous Acute Pancreatitis | Deficient Panc. Ferments | Roentgen Ray Evidence of Calculi | Pancreatico-duodenectomy | Total Panc. | Follow-up Result |
|---|---|---|---|---|---|---|---|---|---|
| 671642 | M | 42 | 9 months | No previous operation | Markedly in all 3 ferments | Positive in head of pancreas | Head and all of duodenum and antrum of stomach | | 2 yr. F.U. Relieved of pain. Normal digestion working at full capacity |
| 672681 | M | 48 | 6 years | 9 mos. previously operation showed edema and large head pancreas | Markedly in all 3 ferments | Positive in head of pancreas | Head, all of duodenum and antrum | | 3 yr. F.U. Relieved of all former pain. Normal digestion. 98 per cent fat absorption |
| 754745 | M | 45 | 5 years | 4 mos. previously operation a large mass was found in head | Markedly in all 3 ferments | Calcium shadows outline shape of pancreas | Total duodenectomy, antrum of stomach. Splenectomy. All of pancreas save a strip over superior mesenteric vessels | | Several postoperative visits, last one 20 mos. after operation. Relieved of epigastric pain. Takes capsules of pancreatin to maintain fat digestion |
| 762485 | F | 26 | 10 mos. | 1 yr. ago in Harlem Hosp. for acute abdomen. Diag.: ptomaine poisoning | Marked deficiency in all 3 ferments | Calcium shadows outline all the pancreas | Total pancreatectomy. Total duodenectomy. Resection of antrum of stomach | | 5 mos. later developed active pulmonary Tbc. 1 yr. postop. is in tuberculosis hosp. Requires 30-80 units of insulin to control her diabetes. Entirely free from pain |
| 784094 | F | 46 | 10 weeks | No history of previous pancreatitis. 5 wks. ago. Celiotomy revealed large pancreas that "felt like a bag of shot" | Markedly in all 3 ferments | Calcium shadows outline entire shape of pancreas | Total pancreatectomy. Splenectomy. Total duodenectomy. Resection of antrum of stomach | | Patient died on 7th day after operation. Autopsy revealed a localized bile peritonitis and a thrombosis of large branch of portal vein |

FIG. 1



FIG. 2





FIG. 3



FIG. 4

FIG. 1.—C. F. Unit #672681. Case 2. X-Ray film showing calculi in head of the pancreas.
FIG. 2.—I. S. Unit #762485. Case 4. X-Ray film showing calculi throughout the entire pancreas, before operation.
FIG. 3.—I. S. Unit #762485. Case 4. X-Ray film of abdomen taken after operation.
FIG. 4.—B. B. Unit #784094. Case 5. X-ray film of abdomen showing calculi throughout the pancreas, before operation.

or the tail of the pancreas, or the entire organ may be outlined by the calcareous material (Figs. 1–6). Next in importance is the finding of a marked deficiency in one or more of the pancreatic ferments, as determined from duodenal aspiration with the administration of metholyl chloride.

Many patients with mild epigastric distress or intermittent pain showing roentgenologic evidence of varying degrees of calcareous deposits are amenable to dietary and medical regimen, and may go for a period of years



FIG. 5.—B. B. Unit #784094. Case 5. X-Ray of abdomen taken after operation.

with tolerable symptoms. There are a few patients, however, that fail to respond to conservative therapy and develop such severe recurring or constant pain, requiring hypodermic medication, that life becomes intolerable. It is for such patients, in whom the diagnosis of pancreatic calculi and chronic pancreatitis is established roentgenologically and by pancreatic function tests, that radical resection and even total pancreatectomy is indicated and welcomed by the victim of the disease.

In all five of our patients pain was dramatically relieved. Claggett's[2] patient, in her own words, had been given a new lease on life with the relief of pain. One of our patients had, of necessity, retired from an active busi-

ness and since his operation for the past three years has enjoyed his winters in Florida and his summers in Wisconsin.

The extent of removal of pancreatic tissue in these radical procedures, is determined by the part of the organ showing the calcareous material as seen in the roentgenograms and by the amount of fibrosed tissue. In the cases with the involvement of the head of the organ we have carried out a pancreaticoduodenectomy, as for a carcinoma of the head. In the tail or body we have left the head but have removed the remainder of the organ with the spleen, as the splenic vessels are usually embedded in the fibrosed tissue. In one of our patients we left only a small strip of pancreatic tissue over the superior mesenteric vessels.



FIG 6.—Patient of Dr. Zinninger, by permission. X-Rays of abdomen before operation. X-Ray of specimen of pancreas removed at operation.

These patients all require transfusion therapy during and after operation. We have used silk technic throughout but have used "near-and-far" steel wire closure of the incision through all the layers because of the possibility of temporary bile and pancreatic ferment leakage and to avoid wound disruption. A small rubber tube within a large rubber tube (Fig. 7) for suction drainage is used to insure dry dressings, to avoid skin irritation and, if necessary, to measure bile or pancreatic juice leakage.

In the patients with total pancreatectomy it is essential to have the close coöperation of an internist experienced in the treatment of diabetes in the pre- and postoperative periods. But it has been astonishing in many of the reported cases to note the relatively small insulin requirements of these patients after a total pancreatectomy. It has caused new theories in the minds of physiologists, internists and surgeons.

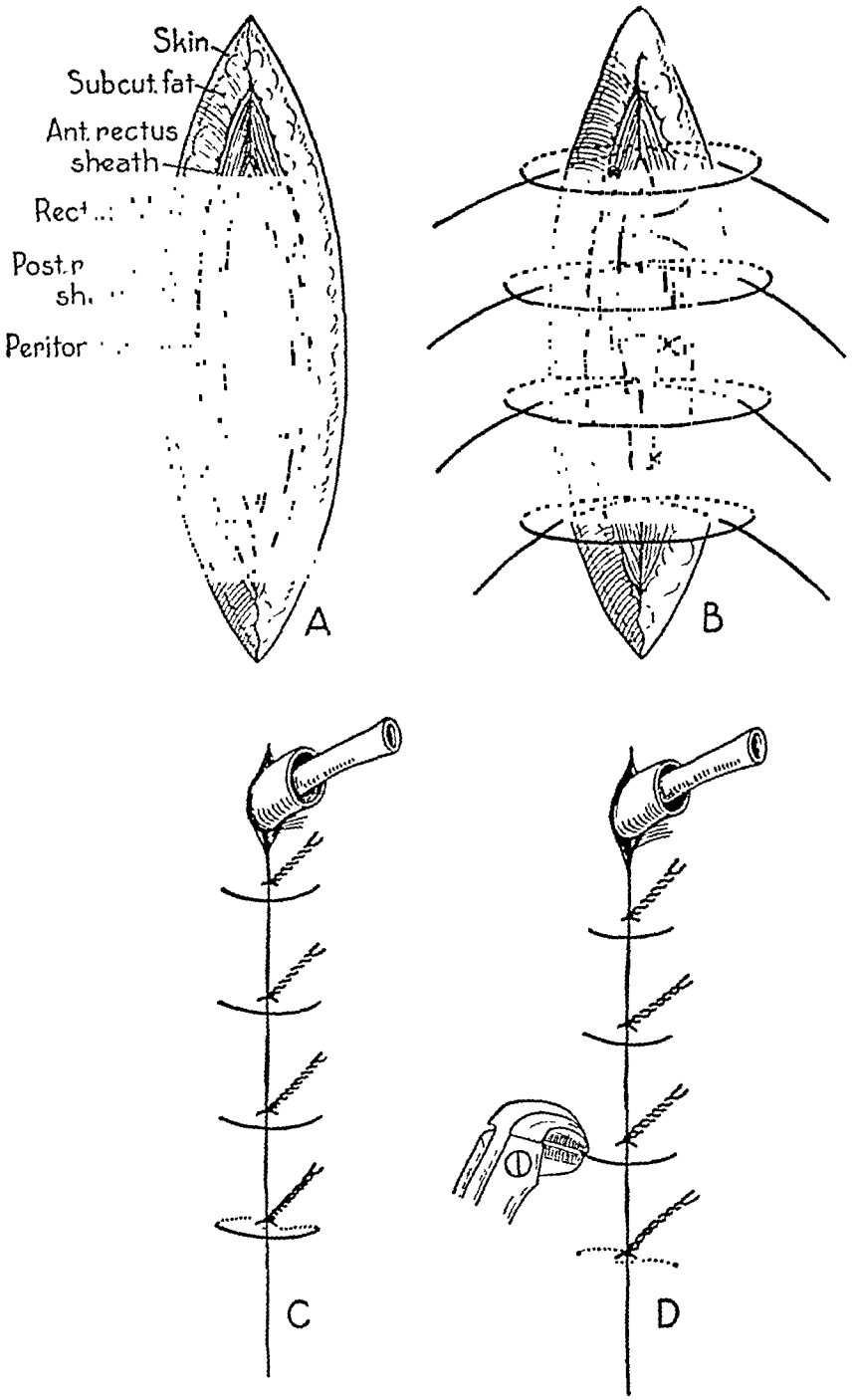



FIG. 7.—"Near and Far, Far and Near" Steel Wire Sutures through all layers for closure of abdominal incision.

Before approximating the wound edges by drawing up and twisting the ends of the steel wires, it is advisable to use interrupted mattress silk or cotton sutures to unite the peritoneum and posterior rectus sheath. No other sutures are necessary for the other layers. The "near and far" wire sutures do not cut the tissues as much as the ordinary retention sutures because the tension is distributed on four rather than on two points. The cross bar of the steel wire is cut at the skin level on the tenth to twelfth day. The next day the twisted ends can be removed.

CASE 1.—Unit No. 671642: F. W., age 42, white, male, salesman. Chief complaint: Attacks of epigastric pain, nine months. F.H. noncontributory. Past: Typhoid at 12. Rheumatic fever at 14. System review irrelevant.

*Present:* He has had vague indigestion for several years. In July, 1941, he had his first attack of midepigastric pain. Cramp-like, later becoming constant, radiating into the back, so severe as to require morphine hypodermically. In November, 1941, February and March, 1942, he had three similar attacks, pain and marked distention, lasting several days with complete relief with morphine, and no symptoms between attacks. No jaundice. Roentgenologic studies taken in Stamford Hospital were not informative. Was treated for neurosis. Physical examination: T.P.R., B.P. normal. No jaundice. Head, neck, chest, extremities, negative. Abdomen: Tenderness and a vague mass in the epigastrium.

*Laboratory Studies:* Blood picture and urinalysis are normal. Fasting blood sugar, 95 mg. per cent. Blood amylase, 61 M.K. units definitely elevated. Pancreatic ferment tests with metholyl chloride show marked deficiency in all three ferments. Duodenal bile examination shows no crystals. Roentgenologic studies show some displacement of the duodenum and stomach and vague shadows suggestive of calcified areas in the head of the pancreas.

*Operation*—5/11/42: Pancreaticoduodenectomy (resection of the antrum of stomach, all of duodenum, 12 cm. of the jejunum, part of common duct) with choledochojejunostomy, cholecystostomy, gastrojejunostomy, pancreaticogastrostomy.

*Findings:* The head of the pancreas was indurated, edematous, so hard that it was thought to be malignant. The true nature of the lesion was not discovered until the pancreas had been divided through the body, where it was found that there were multiple areas of calcification and dilated ducts. Liver and biliary tract appeared normal. Because the lesion in the pancreas was considered malignant the above procedures were carried out.

*Summary of Pathologic Report:* On opening the ducts in the head of the pancreas numerous calculi are found, some of them embedded in the wall of the duct. These vary from 1-4 mm. Numerous areas of focal necrosis are present which show remnants of calculi and epithelium. All sections show an extreme grade of fibrosis of the parenchyma of the organ.

*Postoperative Course:* This was very stormy, with a spiking temperature for three weeks. For a few days his blood cultures showed *B.coli.* He developed a pancreatic fistula. Stools were normal in color and consistency, however. He was discharged on his 36th day. Pain had been entirely relieved.

11/24/42: He was readmitted for closure of his pancreatic fistula. This was done by transplanting the fistulous tract into the loop of jejunum distal to his choledochojejunostomy. Recovery uneventful. No recurrence of pain.

6/14/44: Two years after operation: Feels well, no pain, no indigestion. He has regained normal weight. Stools normal. No recurrence of fistula.

CASE 2.—Unit No. 672681: Admitted 5/25/42. C.F., age 45, white, male, manufacturer. Chief complaint: Epigastric pain, six years. F.H.: Irrelevant. Past: Appendicectomy at 21. Influenza at 24. System review negative.

*Present:* Six years ago he began having intermittent attacks of epigastric pain, colicy in type, at times very severe. Not related to meals. No jaundice until nine months ago when with an acute attack he developed jaundice and signs of acute cholecystitis. Cholecystectomy was performed by Dr. Evans, of Milwaukee, who found an acute gangrenous, noncalculous, cholecystitis together with edema and marked induration and enlargement of the head of his pancreas.

He improved for four months, but in November, 1941, some seven months before admission, he began having very severe epigastric pain radiating to the back, which at times required morphine hypodermically. Roentgenologic studies showed calcified

areas in the head of his pancreas which did not appear before his cholecystectomy. Because of the severe pain and the dread of morphine, he was referred to the Presbyterian Hospital for study and treatment.

*Physical Examination:* T.P.R. normal. B.P. 150/100. Wt. 130 lbs. A well-developed, well-balanced male. No jaundice. Head, neck, chest and extremities normal. The abdomen shows right rectus R.L.Q. scars, and a questionable mass in the epigastrium.

*Laboratory Studies:* Blood picture normal. Urinalysis, normal. Pancreatic function test with mecholyl chloride shows very low values for all three ferments. Serum amylase: 30.9 Myer-Killian units (at upper limit of normal).

Glucose tolerance test: Indicates disturbed carbohydrate metabolism as seen in latent diabetes. Roentgenologic studies show a collection of calcium shadows in the head of the pancreas. The study indicates definite pathology in the head of the pancreas.

*Operation.*—5/26/42: Pancreaticoduodenectomy (resection of the head and part of the body of the pancreas, the pylorus, all of the duodenum, first 10 cm. of the jejunum and part of the common duct). Gastrojejunostomy, choledochojejunostomy, implantation of the pancreatic duct into loop of jejunum.

*Findings:* The major part of the pathology was found in the head of the pancreas where there were numerous calcified casts of the branches of the pancreatic duct, with marked induration of the head which on biopsy showed no tumor. The pancreatic duct and the common duct were markedly dilated. Gallbladder was absent. Liver appeared normal, showing no evidence of fatty degeneration.

*Pathologic Report:* Summary, this appears to be very extensive chronic fibrous pancreatitis with pancreatic calculi in dilated obstructed ducts. The common duct showed no stones. There was no evidence of tumor tissue in any of the many sections examined, but all sections of the pancreas showed fibrosis of the parenchyma.

*Postoperative Course:* Was much smoother than was expected. Wound healed kindly. No fistulae. Pain was entirely relieved. Bowel movements, one a day, appeared normal. Discharged on his 23rd day.

*Follow-up.*—2/27/45: Two years, nine months, after operation came in for a check-up. He has maintained his weight, has no indigestion, no food intolerance. His former pain has been entirely relieved. Blood studies are normal. Fat absorption study: On a three-day measured fat intake and output test he shows 98 per cent fat digestion.

5/26/45: Three years after operation, letter from patient states he feels well and has had no recurrence of pain.

CASE 3.—Unit No. 754745: Admitted 7/20/44. C. H., age 45, white, male, machinist. Chief complaint: Severe epigastric pain at irregular intervals for five years. F.H. Irrelevant. Past: Typhoid fever and osteomyelitis of tibia 16 years ago.

*Present:* In 1901, cholecystectomy and appendicectomy were done for lower abdominal pain in another hospital. In 1939 he began having severe, gnawing pain in epigastrium and left upper quadrant, radiating to the back. In 1941, this pain became very severe and during the two weeks of the attack he lost 20 lbs. For three years he improved but pain persisted. In February, 1944, the pain recurred in very severe form, and he developed jaundice. In March, 1944, he was operated upon in Washington, D. C. An orange-sized, hard mass was found in the head of the pancreas which appeared calcified. The common duct was drained by a T-tube. Because of persistent pain requiring morphine he was referred to the Presbyterian Hospital.

*Physical Examination:* A tall, thin male complaining of pain in L.U.Q. No jaundice. Head and chest and blood pressure are normal. The abdomen reveals two right rectus scars, the mesial one wearing a T-tube. There is tenderness along the epigastrium and L.U.Q.

*Laboratory Data:* Blood count and blood picture is normal. Urinalysis shows no albumin or sugar. Fasting blood sugar, 97 mg. per cent. Serum amylase 42 Myers-Killian units. Pancreatic function test with 10 mg. mecholyl chloride shows marked deficiency in all three ferments, indicating wide spread disease. Duodenal bile drainage: Light green. No crystals. Roentgenologic studies show a series of calcium shadows occupying the position of the pancreas. These shadows vary in size, some as large as 4 x 7 mm. Some of these in the head of the pancreas suggest the outline of a cyst.

*Operation.*—7/29/44: Pancreaticoduodenectomy, splenectomy, resection of tail and most of the body of the pancreas (the only part remaining was a narrow strip overlying the superior mesenteric vessels). Choledochojejunostomy. Gastrojejunostomy. Incision: Transverse.

*Pathology:* The findings in this patient corresponded fairly accurately with those that had been reported in his previous operation by Dr. Anderson. There were very dense adhesions between the colon and omentum, and omentum to anterior abdominal wall, and under surface of the liver and duodenum which required a good hour of careful dissection in order to determine the feasibility of a radical procedure. The pathology in the pancreas was exceedingly interesting. The mass in the head of the pancreas had decreased considerably in size as compared to that noted by Dr. Anderson, at which time it was said to be about the size of an orange. The head of the pancreas was definitely indurated and hard and contained numerous areas of calcification, as shown by his roentgenograms. When the head of the pancreas was cut through at the right hand margin of the portal vein and superior mesenteric vessels there were areas that were almost rock-like in consistency and evidently were the site of calcareous degeneration. The entire body and tail were hard and indurated. No large cyst was encountered. A total pancreatectomy was considered impossible in this case because of the difficulty of dissecting this indurated calcified tissue from the portal vein and superior mesenteric vessels. For this reason a zone about 2 cm. in width was left, covering the portal vein. All of the pancreas to the left of the portal vein, together with the tail of the pancreas and the spleen were removed. The prepyloric part of the stomach, the pylorus and duodenum and head of the pancreas to the right of the portal vein, the duodenojejunal junction and about 6 or 7 cm. of jejunum were removed, making a second specimen.

The T-tube, which had been used at the first operation in March, was still in place. For this reason the common duct was not dilated, but it could be identified by the presence of the T-tube and because it was considered unwise to break up the opening in the common duct by removing the tube at that time it was left in place and was used as a guide in getting through the common duct near its entrance into the posterior wall of the duodenum.

*Procedure:* The patient had had two previous right rectus vertical incisions and for this reason an oblique transverse incision above the umbilicus was used. This gave very good exposure and made it possible to do the splenectomy and removal of the tail of the pancreas much more readily than if a right rectus incision had been used. A considerable amount of time (almost an hour) was used to dissect the dense adhesions described above, by sharp dissection. The lesser sac was entered after ligating the vessels in the gastrocolic omentum up to the point of the hilus of the spleen. This made it possible to remove the spleen with the tail of the pancreas and because it was essential to control the branches of the splenic vessels to the pancreas the spleen was removed. The pancreas was then dissected to the junction of the splenic and superior mesenteric vessels. The inferior mesenteric joined the splenic near this point. The pancreas was cut through and its stump was covered over by interrupted mattress sutures of No. 1 Deknatel. The duodenojejunal junction was then identified and about 6 or 7 cm. beyond this point an incision in the mesentery of

the jejunum was made and the vessels ligated, leaving a good supply to the lower jejunal limb which was made by dividing the jejunum at that point. The proximal part of the jejunum with the duodenojejunal angle was brought up through a rent in the mesocolon and this, together with the duodenum and head of the pancreas, was dissected up to the superior mesenteric vessels and the beginning of the portal vein. The stomach was cut through the prepyloric portion and the distal stump, together with the duodenum and severed head of the pancreas was then removed, after cutting through the common duct below the point where the T-tube was seen. Hemostasis was established. No dilated duct could be made out and the right hand stump of the pancreas was then closed with interrupted No. 1 Deknatel sutures. The distal segment of jejunum was then brought up through the rent in the mesentery. The mesenteric half of the cut end of the jejunum was then closed with an over-and-over stitch of silk and about 1 cm. of the remaining opening of the jejunum was then anastomosed to the cut-end of the common duct after uniting the serous coats with continuous C silk and the two stomas then united with a continuous over-and-over suture of No. 000 chromic on an atraumatic needle. The seroserous suture was then resumed to the point of beginning and the mesenteric border of the cut-end, which had been closed, was then tacked to the gastrohepatic omentum with interrupted silk sutures. The stump of the stomach was then approximated to the jejunum. The two serous surfaces were united with continuous C silk. An opening in the jejunum corresponding in length to the cut-end of the stomach was made, hemostasis established, and the two openings united by means of No. 00 chromic on two atraumatic needles with an over-and-over stitch, beginning at the center of the two adjacent parallel cut-edges, locked at the angles and carried around to a point opposite the point of beginning. The seroserous suture was then continued to the point of beginning. This completed the anastomosis.

The peritoneal toilet was completed. A large soft rubber tube, containing a small tube inside of it for suction purposes, was placed in Morrison's pouch for possible leakage and the wound was closed with far-and-near steel wire sutures, steel wire being used because of the possibility of pancreatic or jejunal leakage. The T-tube was left in the original position above this incision.

*Postoperative Course:* A stormy four days during which time he required plasma and blood transfusions. His temperature ranged from 101°–104°F. for nine days. From then on he improved steadily. Wounds healed well. He was able to overcome his desire for hypodermic medication. He was discharged on his 27th day. Before leaving, a fat tolerance test done for three days on a measured fat intake and output showed that he was digesting 87 per cent of his fat intake. He was relieved of his pain. He was given ten units of insulin a day for an elevated blood sugar.

He has been followed several times by visits to the hospital. Twenty months after operation, he is relieved of his epigastric pain; he has no glycosuria with 10–15 units of insulin. His stools are normal if he takes small doses of pancreatic extract. He is working regularly.

CASE 4.—Unit No. 762485: Admitted 1/26/45. I. S., age 26, colored, married, laundress, separated. Chief complaints: Epigastric pain and voluminous, frequent fatty stools for ten months. F.H. One of 15 children, married, separated. One child eight years old, Husband had chronic cough.

*Past:* System review negative. One year ago was in Harlem Hospital for severe abdominal pain. Diagnosis: "Ptomaine poisoning." Ten months ago she began to have severe crampy epigastric pain associated with frequent bulky, fatty stools. Has had loss of weight and strength. Recently she has had more severe epigastric pain radiating to her back.

*Physical Examination:* A thin, unintelligent colored woman. No jaundice. The examination of the lungs reveals no pathology. A soft blowing systolic murmur is heard at the apex, not transmitted. There is some tenderness across the upper abdomen

along the site of the pancreas. Examination of the rest of the abdomen, the pelvis and extremities is negative.

*Laboratory Studies:* Blood picture is normal. Urinalysis reveals no glucose or albumin. Serology negative for lues. Stools show bundles of fatty acid crystals. Duodenal bile drainage negative. Pancreatic function tests with 10 mg. mecholyl chloride reveal low amylase, very low protease, small amount of lipase. Serum amylase: normal. Glucose tolerance reveals a diabetic curve. Cholecystogram shows no evidence of a gallbladder shadow. Plain films of the abdomen show numerous shadows of varying size and calcium density that almost outline the pancreas. *Diagnosis:* Diffuse pancreatic lithiasis.

*Operation.*—2/3/45: Total pancreatectomy, pylorectomy, total duodenectomy, choledochojejunostomy, and gastrojejunostomy.

*Pathology:* The findings in this patient proved to be unusually interesting and corresponded fairly accurately to the roentgenologic studies which had been made, showing extensive calcification of all of the pancreas with areas that might well have been pancreatic calculi. When the abdomen was opened the gallbladder was found to be normal. There were no stones. It was normal in color and it emptied easily. The liver appeared to be normal. There was no evidence whatsoever of fatty degeneration. The pathology was all confined to the pancreas—and there was plenty of it. On exposing the pancreas through the gastrohepatic omentum the body and tail could be seen and palpated. There was an extensive cystic degeneration of the body and tail as well as of the head, and on palpating it there were numerous movable calculi, which gave the feel of a gallbladder containing numerous stones. The body of the pancreas was much larger than normal, probably due to the extensive cystic degeneration. The head was similarly involved; the tail probably less than the body and head. The head of the pancreas, however, showed an unciform process which surrounded the superior mesenteric vessels and made removal of the pancreas difficult. The common duct was not dilated and when it was cut through near the duodenum it was found that the cystic duct ran parallel to it so that, if the duct had been ligated and the gallbladder used as a by-pass, no bile would have been available for emptying into the gallbladder. Because the patient showed all of the evidences of pancreatic deficiency in the presence of fatty stools and because the patient had had fatty stools, it was decided to do a total pancreatectomy. The etiology of the pancreatic calcification seemed to be the result of a previous acute pancreatitis, for there were very numerous filmy adhesions throughout the peritoneum. In places there were sheets of very delicate membrane, resembling fetal membrane. One of these measured in extent the size of the patient's anterior abdominal wall. The lesser sac was obliterated and the only etiology for the calcification seemed to be an acute pancreatitis, the history of which the patient gave in one of her many inaccurate statements that she had been taken to Harlem Hospital a year ago with a diagnosis of acute ptomaine poisoning.

*Procedure:* A transverse incision was made through both recti and splitting the obliques. The pancreas was approached through the lesser sac where, because of the low position of the stomach, it was possible to free the tail of the pancreas and the body without apparent damage to the splenic artery and vein. After this was done it was decided to remove the duodenum because of the intimate blood supply between the pancreas and the duodenum, and this was carried out by first applying crushing clamps at the duodenojejunal angle, the first portion of the jejunum being drawn up into the right upper quadrant. The duodenum was severed and the distal end was closed with an over-and-over suture of No. 1 silk, followed by a burying suture of No. 1 silk. The duodenum was mobilized with the head of the pancreas, but there the unciform process was found and it was decided to sever the common duct, and after ligating the gastroduodenal vessels the antrum of the stomach was cut through near the pylorus and the body of the pancreas, together with the head, was then dissected away from the superior mesenteric vessels and the portal vein. This was a

difficult and trying dissection because there were numerous tributaries to the portal which had to be carefully ligated, but after the pancreas had been removed with the duodenum the superior mesenteric and the splenic could be easily seen. The inferior mesenteric was not identified. Hemostasis was satisfactory.

A loop of jejunum near the duodenojejunal angle was then brought up anterior to the colon and a choledochojejunostomy was done between the cut-end of the duct and the jejunum by means of a seroserous suture, followed by an over-and-over No. 000 chromic suture of the duct to the small opening in the jejunum. The seroserous suture was then resumed to the point of beginning. About 12 cm. distal to this anastomosis the stomach was anastomosed to the jejunum, end-to-side, using the same technic.

The pancreas having been removed, there was no danger of pancreatic fistula, and a soft rubber tube containing a smaller rubber tube inside of it was placed to Morrison's pouch to take care of leakage. Closure: Steel wire near-and-far sutures.

*Pathology Report—Gross:* The specimen consists of a small segment of the pyloric end of the stomach and all the duodenum, which, in the fresh state, measure together 10 cm. in length. In the curve of the duodenum and attached to it is a nodular, hard, irregular pancreatic head, measuring 6.5 cm. in greatest dimension. This is attached to the rest of the pancreas and the total length of the organ is 19 cm. Toward the tail there is an irregular thickening and at this site the diameter is 5.5 cm. In the fresh state, particularly in the body of the organ, the tissues feel soft and contain great numbers of calculi.

After fixation and opening the duodenum, it is seen that the pyloric ring is situated about 2 cm. from the inversion. The papilla is not clearly seen, but on opening the common duct along a probe, it appears that in clamping the duodenum the papilla has been included in the clamp. There was apparently a very low point of entry. The opening of the pancreatic duct cannot be made out. The pancreas is, therefore, sectioned. It is an effort to find this opening. The organ is everywhere pitted by large, irregular cavities containing calculi. A greatly dilated pancreatic duct is found which courses irregularly to the head of the organ and is blocked by calculi. These stones are white, heavily calcified, but markedly friable. No normal pancreatic tissue is recognized even in the extreme tip of the tail. Everywhere there are craters surrounded by sense scar tissue. Fixation — formalin.

*Microscopic:* Section through the head of the pancreas shows ducts with incomplete epithelial lining, greatly distended and containing calculi. Where these have been incompletely decalcified, calcium is seen in section. There is a little granular material about these calculi and occasionally a few polymorphonuclear leukocytes are present. The pancreas is represented outside these ducts by dense cicatricial tissue in which there are widely separated small islets and small ducts. These small ducts are likewise dilated. Remnants of pancreatic acini are seen in a few fibrotic lobules. There is not any significant inflammatory reaction except in the vicinity of the larger ducts, where there are scattered lymphocytes. This same picture is seen in the body of the pancreas and the dilatation of ducts extends to the tip of the tail. The islet tissue is scant throughout. There is no suggestion of carcinoma.

Section taken through the duodenum in the hope of demonstrating a remnant of common duct fails to do so. It shows some cystic dilatation of some of the crypts of the duodenal glands.

Section of the liver biopsy shows no cirrhosis and no cholangitis. Some of the cells are distended by what is probably glycogen.

Section of the peritoneal adhesions shows a membrane composed of an exceedingly thin layer of stroma in which there are only occasional connective cells and no recognizable blood vessels. A single layer of peritoneal cells, flattened, except for their bulging nuclei, constitutes the surface. Unfortunately, this tissue was not impregnated

fresh with silver, so the structure of the surface cells cannot be demonstrated. *Diagnosis:* Chronic pancreatitis. Pancreaticolithiasis. Peritoneal adhesions. Liver.

*Postoperative Course:* Immediate recovery excellent. Out of bed on fourth day. Sugar in blood and urine was controlled by varying amounts of insulin — 30–60 units o.d. The patient was rather ignorant and uncoöperative but before leaving the hospital on the 34th day she had been taught the use of hypodermic for insulin therapy and urinalysis for glucose. The epigastric pain had been entirely relieved. Her stools every day or q. 2 days. Normal in color and amount.

7/24/45: Readmitted for study and because she had developed a cough. Requires now between 30–70 units of globin insulin, on a 300–70–75 diet. Stool studies on a measured fat intake and output over a three-day period show she has 76 per cent absorption. With three tablets of pancreatin after each meal, a later test showed she had absorbed 83 per cent of her fat intake.

Sputum examination reveals tubercle bacilli and roentgenograms of chest shows a cavity in right upper lobe.

The patient was transferred to the Sea View Hospital for tuberculosis. A note from the hospital dated February 20, 1946, one year after pancreatectomy, says: "The right hemithorax is narrowed in volume and suggests the presence of considerable fibrosis in the lung or pleura. The left lung is free of infiltrate. Sputum has been positive. Her diabetic condition is well-controlled by protamin zinc insulin 84 units. Since admission she has presented a personality problem. At times she refused to eat or take her insulin. She has refused to have her temperature taken and at times refused to waken when rounds are made. Her temperature is still fluctuating."

CASE 5.—Unit No. 784094: Admitted 4/21/45. Died 5/7/45. B. B., age 46, white, female, school teacher. Chief complaint: Severe epigastric pain — ten weeks. F.H. — Irrelevant. Past: Influenza 1919. Incision of perirectal abscess in 1940.

*Present:* She was in relatively good health until 11 weeks ago when she began having voluminous, foul putty-like stools. Ten weeks ago she developed a severe, gnawing epigastric pain radiating to her back, made worse by eating. She was explored in another hospital five weeks later. The surgeon found a remarkable pancreas, having the feel of a "bag of shot," and chocolate cyst of the left ovary. Appendicectomy and left salpingo-oophorectomy was done. The epigastric pain persisted, increasing in severity. Nausea and vomiting appeared. She had lost 20 lbs. in two months.

*Physical Examination:* Temperature, pulse, blood pressure were normal. She appeared to be a thin middle aged woman evidently in severe abdominal pain. No jaundice. Lungs clear. Heart normal. The abdomen showed a midline scar. There was marked epigastric tenderness. No masses or viscera were felt.

*Laboratory Findings:* Blood count normal. Urinalysis: 1026, acid, albumin 2+. Glucose 4+. No ketone bodies. Blood sugar 106 mg. per cent. Serum amylase 32 units (Myers and Killian). Pancreatic function test (mecholyl) shows striking deficiency of all three ferments. Plasma protein 7.1. Urea nitrogen normal. Serum $CO_2$ 54. vol. per cent. X-ray films of abdomen show extensive calcium shadows in all parts of the pancreas.

*Operation.*—4/24/45: Total pancreatectomy, total duodenectomy, pylorectomy, splenectomy. Antecolic choledochojejunostomy and gastrojejunostomy. Transverse incision.

*Surgical Pathology:* The only abnormality was in the pancreas. It was enlarged throughout, was of fibrous consistency except for cystic areas which contained many large and small calculi, giving the "bag of shot" feel noted by the surgeon at the first operation. The liver and gallbladder appeared normal in every respect. The common duct was not dilated.

*Pathologic Report: Gross:* The specimen consists of a large pancreas resected

together with the pylorus of the stomach and all of the duodenum. An additional specimen consists of the spleen, removed separately, and a biopsy of the liver. The pancreas measures 16 cm. in length and 4.5 cm. in width across the body. The head is considerably injected, measuring 8 cm. from above downward and 5.5 cm. from side to side, 3 cm. in thickness. A large portion of this consists of an exaggerated uncinate process in which the groove for the portal vein is found, making it clear that the vein was almost entirely surrounded by pancreas. The segment of stomach and duodenum removed measures approximately 26 cm. in length. The distal portion of the duodenum is hemorrhagic and the serosal surface is torn, apparently from operative trauma. The common duct on the posterior aspect of the head measures about 5 mm. in diameter. There is no suggestion of bile-staining of the tissue. There is a prominent hard lymph node at the lower border of the uncinate process. Palpable through the organ, except at the extreme tip, there are large, grating, irregular calcareous masses. The spleen weighs 80 grams and except for rather deep indentations on the anterior border, is not unusual. The liver biopsy is too small for gross description. The lesion is fixed in Kaiserling before section. After 24 hours fixation the specimen was opened by bisecting the body and tail of the pancreas and making serial sections of the head. The common duct, which was not dilated, was also opened along its length and traced into the ampulla. It was seen that the ducts were blocked by large, irregular calcareous masses with surfaces like fine white coral. The ducts of Wirsung and Santorini enter together and are separated from the common duct. The duct of Wirsung is greatly dilated where it is filled with calculi, measuring as much as 1.5 cm. in diameter. It is dilated throughout the length of the specimen and tortuous. The cut-surface of the pancreas appears as a number of small round openings which are surrounded by dense fibrous tissue. No normal pancreas is recognizable. Fixation—Bouin.

*Analysis of the Calculi:* The calcareous material was powdered and dried in vacuum and then it dissolved in hydrochloric acid with the evolution of gas. There was some slight organic residue but most of the material went in solution. Analysis showed that there were 42.4 mg. of cholesterol in the 111 mg. of stone. This is practically the theoretic amount to be expected if one assumes that the material is pure calcium carbonate.

*Microscopic:* Section through the head shows numerous irregularly dilated ducts surrounded by a fairly heavy collar of connective tissue. Peripheral to this collar there are smaller dilated ducts and a considerable number of islets. No recognizable scinar cells are seen. Some of the structures interpreted as ducts might conceivably be atrophic acini. Section through the tail shows a similar picture but here there are a few structures which may be interpreted as pancreatic acini.

I have discussed these findings with Dr. Dorothy Andersen who says that they are, with the exception of the calculus formation, similar to the changes in congenital cystic fibrosis of the pancreas where the obstruction depends on plugging of the ducts with secretion, not calculi. The reason for the calculus formation is obscure. This is not calcification of the pancreas on the basis of the previous inflammation but it is cystic fibrosis following obstruction. *Pathologic Diagnosis:* Pancreaticolithiasis. Fibrosis of pancreas.

*Postoperative Course:* The temperature rose from normal to 103°F. and remained elevated until a terminal 105°F. On the first day the shock was controlled by parenteral fluids and transfusion. Plasma proteins fell to 4.4, however, in spite of additional plasma and blood. Insulin 50-90 units failed to control the glycosuria. There was no ketonuria. On the fourth day she went into shock again but this was controlled by transfusion. Because of the large amount of gastric Levine tube drainage, a high ileus was suspected. She was reëxplored. Some distention of the jejunal loop with edema was found. An anterior gastrojejunostomy was done. The patient went into severe shock, developed a pulmonary edema and died on the seventh day after her pancreatectomy.

*Autopsy:* The essential findings were a localized fibrinous bile peritonitis about the choledochojejunostomy, with edema of the stoma obstructing the flow of bile into the jejunum. A large branch of the portal vein was filled by an organizing thrombus and there were thrombi in some of the intrahepatic branches. The proximal loop of the jejunum was edematous but not obstructed. Sections of the liver showed areas of central focal necrosis. The gallbladder shows edema and early acute cholecystitis.

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DISCUSSION.—DR. RICHARD B. CATTELL, Boston, Mass.: We have had three patients with diffuse calculi and calcification of the pancreas, none of whom have been operated upon. I wish to call attention to the probable cause of pain in these cases and a possible means of relief without extensive resections. We have been able to relieve pain in cases of inoperable carcinoma of the pancreas with obstruction of the duct of Wirsung by anastomosing the duct of Wirsung to a defunctionalized loop of jejunum. This is not a difficult technical procedure and we have performed it in nine cases. After division of the gastrocolic omentum, a long antecolic loop of jejunum is brought up and anastomosed to the duct in the midportion of the body of the pancreas over a T-tube. It is quite possible that the same procedure could be utilized in calculous disease of the pancreas, although it would have no effect on the diffuse calcification. I suggest it as a possible means of relieving pain by a less radical procedure than total pancreatectomy.

DR. REGINALD H. SMITHWICK, Boston, Mass.: I hesitate to comment upon Doctor Whipple's presentation because my experience with this problem is confined to one case, because a different form of treatment was employed, and because the follow-up of the case to which I refer is of very short duration, six months.

This patient was a female in her early 50's and for some months she had been suffering from frequent excruciating attacks of deep-seated midepigastric pain, occurring principally at night and requiring large amounts of morphine for relief. She had calcification of the head of the pancreas. She had had a previous cholecystectomy. She was thought to have a duodenal ulcer also. She had severe diabetes and hypertension of moderate severity, associated with considerable evidence of cardiovascular damage.

Because of her general condition, Doctor Allen, whose patient this woman was, and I were a little hesitant about resection of the pancreas in this particular case. Also, while we presumed that the pain was arising from intermittent distension of the pancreatic ducts, study of other possible visceral pain pathways by balloon distension of the lower esophagus, various portions of the duodenum and the upper jejunum, indicated that the same identical pain could be reproduced by stretching of any of these areas. This made us feel that this particular patient might continue to have attacks of abdominal pain following resection of the pancreas—as we have known it to recur after operations upon the biliary tract in particular.

We decided to section the viscerosensory pathways of the pancreas, the upper gastro-intestinal tract, and the lower esophagus. This was accomplished by transthoracic resection of the sympathetic trunk on the right side from D–3 to D–12, inclusive, and the great splanchnic nerve from the celiac ganglion to the midthoracic level. Since the pain was in the midline, we had expected that a bilateral procedure would be necessary, but so far there has been no recurrence of the pain.

Doctor Whipple's operation is a direct approach to the pathologic process and is, consequently, more logical. In general, the sectioning of viscerosensory pathways for the relief of abdominal pain of visceral origin should be employed as a last, not as a first resort. I mention this case simply to call attention to a possible alternative to resection of the pancreas, which may prove to be worth considering particularly in poor risks or complicated cases.

DR. ALEXANDER BRUNSCHWIG, Chicago, Ill.: I think the cases Doctor Whipple presents show a new indication for total pancreatectomy. I have not had occasion to perform this for chronic pancreatitis, but only for carcinoma. I have seen patients with extensive calcification in the pancreas and severe pain, who received exploratory celiotomy elsewhere and, because of firmness and enlargement of the pancreas the diagnosis of carcinoma was made. Morphine was not withheld but was given freely and they had become confirmed addicts.

On the other hand, we have seen patients who present almost no symptoms, certainly not enough to warrant any procedure on the pancreas, and yet roentgenograms showed extensive pancreatic calcification. Why the difference in symptomatology with apparently the same pathology? This is well worth further study. One other point; in two patients who had undergone total pancreatectomy there was postoperative insulin sensitivity. We had felt that large doses of insulin would be necessary but this did not prove to be the case. In one instance, ten units of insulin produced marked hypoglycemia. One does not have to be concerned immediately after operation with supplying insulin; in fact, it is better not to give insulin and become concerned only if and when diacetic acid and acetone appear in the urine.

I should like to hear Doctor Whipple's comments on the stools in his patients. In one patient who had had total gastrectomy as well as total pancreatectomy because of carcinoma, there was no change in the characteristics of the stool. Curiously enough, this patient had had diarrhea for some months before he was admitted for operation. It was semisolid, greenish-yellow and at times frothy. Total pancreatectomy, total duodenectomy and total gastrectomy did not result in change in the character of these stools. The patient succumbed three or four months later of carcinomatosis, and necropsy failed to reveal the cause of the diarrhea.

DR. M. M. ZINNINGER, Cincinnati, Ohio: With reference to the patient upon whom I operated, of whom Doctor Whipple showed the roentgenograms; I observed that man for about three years roentgenologically, and saw progressive increase in calcification and progressive increase in the amount of pain. The pain was at the level of the twelfth rib posteriorly, and for the last three months before operation he was relieved only with 0.5 gr. morphine. Examination of the specimen showed calcification not only in the substance of the pancreas but also in the duct, which was blocked at

more than one level; for that reason drainage of the duct would not have been of any value. We have seen six other cases with calcification of the head of the pancreas in which there was no pain. I believe that the pain must come from blockage of the duct, but simple removal of one stone in this case would not have relieved it.

DR. ALLEN O. WHIPPLE, New York City (closing): I appreciate Doctor Smithwick's presenting the case he reported. I intended to speak of that but I was pressed for time. I think the method he advises is one to be considered. It carries less risk than total pancreatectomy, and further studies should be made in that line.

With regard to Doctor Brunschwig's discussion, we have had a considerable variation in the condition of patients so far as fat tolerance is concerned, and the character of the stools, but at least three out of five that have been having trouble with the stools were relieved after operation, and in three patients where the fat intake and fat output was measured over three days, it showed that they absorbed all the way from 74 to 96 per cent of the fat ingested.

Two other things are difficult to explain. Some cases with extensive calcification had no pain, whereas others have intolerable pain; the other thing is the insulin requirement after total pancreatectomy. Some require little at first and later on require increasing amounts. This is a matter for further study as cases are reported.

# PANCREATITIS AS A CAUSE OF COMPLETE OBSTRUCTION OF THE COMMON DUCT*

J. DEWEY BISGARD, M.D.

OMAHA, NEB.

THE PANCREAS has presented a challenge which has fascinated surgeons and physiologists for more than a century. This challenge, with a sense of frustration, was expressed by Pepper, in 1882, in the words: "It is unfortunate to have much to say, and yet to have no intelligible language in which to express it. This is somewhat the lot of the pancreas." Since that time the gland has become quite articulate but little has been gained in our knowledge of its inflammatory lesions.

The lack of a definitive method of establishing a diagnosis of chronic pancreatitis *in vivo* makes the problem of its relation to obstructive jaundice somewhat speculative. This uncertainty was stated by Moynihan as follows: "It is difficult to be dogmatic about the cause of obstruction (obstructive jaundice). History may be misleading, tests are at best uncertain, and even the final court of appeals, a celiotomy, may leave the position undecided. In the presence of so much uncertainty it is likely that operation will continue to be practiced; and if so, it seems reasonable that having ventured so far an attempt should be made to give relief."

In the majority of individuals (about 62 per cent) the distal end of the common duct is surrounded by pancreatic tissue and it is probable that inflammatory swelling of the encircling pancreatic tissue could cause compression of the duct or involve it in the inflammatory process in such a way as to produce obstruction. Unfortunately, it is impossible to prove this hypothesis. Pancreatitis is seldom if ever an isolated lesion, usually there is associated disease of the biliary system and never is it possible to be certain that other more common and tangible causes of obstruction have not been overlooked. For example, there always exists the irrefutable possibility that an obstructing gallstone has passed spontaneously or has been forced imperceptibly through the ampulla into the duodenum during palpation or instrumentation of the duct.

The literature dealing with this subject is indeed meager. There are several references to chronic pancreatitis in discussions which enumerate all possible causes of obstructive jaundice and some reports of cases in which the diagnosis was made solely upon the basis of operative findings and devoid of follow-up records of sufficient length to exclude an overlooked obstructing neoplasm.

In 1900, Mayo Robson reported 16 cases of jaundice associated with

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chronic pancreatitis as judged by palpation at operation. There was no other demonstrable cause of obstruction of the common duct but none of these cases had been followed longer than two years. In 1904, he reported 24 cases of which six were well from three to 14 years after operation. Two died soon after operation and both showed at postmortem examination a "cirrhotic condition" of the head of the pancreas with compression occlusion of the enclosed portion of the common duct. There were no evidences of neoplasm and no stones in the ducts.

Mikulicz, in 1903, reported a case, which at operation, he assumed to be a carcinoma of the head of the pancreas. The patient died ten days after operation and necropsy revealed the intrapancreatic portion of the common duct occluded by compression from what proved to be on section chronic inflammation of the pancreas. He recalled similar cases in which long periods of survival in good health following internal or surface drainage of the biliary system made it necessary to revise the operative diagnosis of carcinoma to that of pancreatitis.

Rowlands, in 1910, reported two likely cases but both were followed less than two years.

In 1932, Walters and Dehne reported 113 cases operated upon for jaundice which resulted presumably from obstructing lesions in the pancreas. Of those that survived operation, two were well 13 years later, one, nine years, and two, eight years. In these cases it seemed reasonable to assume that the obstruction had resulted from inflammation of the pancreas. They reported also five cases in which postmortem examination revealed inflammatory lesions of the pancreas and no other demonstrable cause of the obstructive jaundice. In a later publication Walters related that he had encountered cases of ulcer of the posterior wall of the duodenum which had perforated into the pancreas and the associated inflammation had caused obstruction of the common duct.

In 1937, Frazier was asked by the Council of the Association of Surgeons to investigate and report: "The End-results of the Surgical Treatment of Obstructive Jaundice in Relation to Pancreatic Disease." To obtain adequate material for this study, he circulated a questionnaire to all leading British surgeons and 172 responded, providing a pooled experience with 1,035 cases. Of this series, obstructive jaundice resulted presumably from chronic pancreatitis in 238 cases. The diagnosis of chronic pancreatitis was based upon either autopsy findings or impressions from observations at operation plus a sufficient survival period to exclude an overlooked obstructing carcinoma. One hundred seventy-two cases had satisfactory follow-up records, and 135, or 80 per cent, were living and well from one to ten years following operation. One hundred forty-four were treated by internal drainage and 53 by surface drainage.

It is interesting that in 88 per cent of the cases with malignant disease the gallbladder was much enlarged and tense, whereas in 85 per cent of cases

classified as chronic pancreatitis the gallbladder was thick-walled and usually contracted with and without stones. Furthermore, it was noted that pancreatitis occurred in a much younger group and that the jaundice was less intense and came on with less antecedent symptoms than carcinoma.

Carter and Hotz reported six cases, five of which had no follow-up records but in two of these biopsies were obtained from the pancreas at operation and both showed microscopic evidence of chronic inflammation. In one case necropsy revealed conclusive evidence of chronic pancreatitis constricting the common duct.

It is the purpose of this paper to report two cases of obstructive jaundice in which an existing pancreatitis, as judged by operative findings and blood amylase studies, was the only demonstrable cause of obstruction of the common duct. In both cases the common and the hepatic ducts were dilated, in one, only moderately, in the other, enormously, and in both the bile in the ducts was thick and slightly muddy and in one under pressure. The head of the pancreas in both cases was much larger than normal, nodular, firm and tense. Intraductal investigation revealed no gallstones or other source of obstruction. After some hesitation from resistance small sounds passed into the duodenum. In both cases the gallbladder was much smaller than normal, contracted, thick-walled and contained no stones, and in both it contained bile not unlike that present in the ducts. The liver function studies in both cases were consistent with extrahepatic type of jaundice and the blood amylase was elevated to levels which reflect pancreatic disease.

Further evidence in support of the hypothesis is found in the fact that both cases recovered following prolonged drainage of the common duct.

One case has remained well and free from jaundice, now three years following operation. This fact is important principally in dispelling the possibility of a neoplasm as the cause of obstruction. The other case was well and free from jaundice for seven months. He then developed an intense jaundice and died in five days of an acute hepatitis. In this case a preoperative diagnosis of malignant disease had seemed a certainty, but the postmortem examination excluded this possibility.

The most convincing evidence in support of the hypothesis was revealed in the postoperative choledochograms (Figs. 1, 2 and 3). In both cases the common duct and hepatic ducts filled completely and without filling defects except in the distal portion of the common duct, where there appeared to be a tapered uniform constriction through which the radiopaque solution passed freely in one case and only when placed under pressure in the other one. Subsequent serial choledochograms (Fig. 2) were made in one case and these show a progressive increase in the filling of the constricted portion of the duct, interpreted as evidence of dilatation from release of constriction.

Furthermore, it should be emphasized that jaundice developed in the one case in the absence of real pain and in the other in the absence of colic but with pain which was relieved by antiacid medication.

FIG. 1-A

1-B



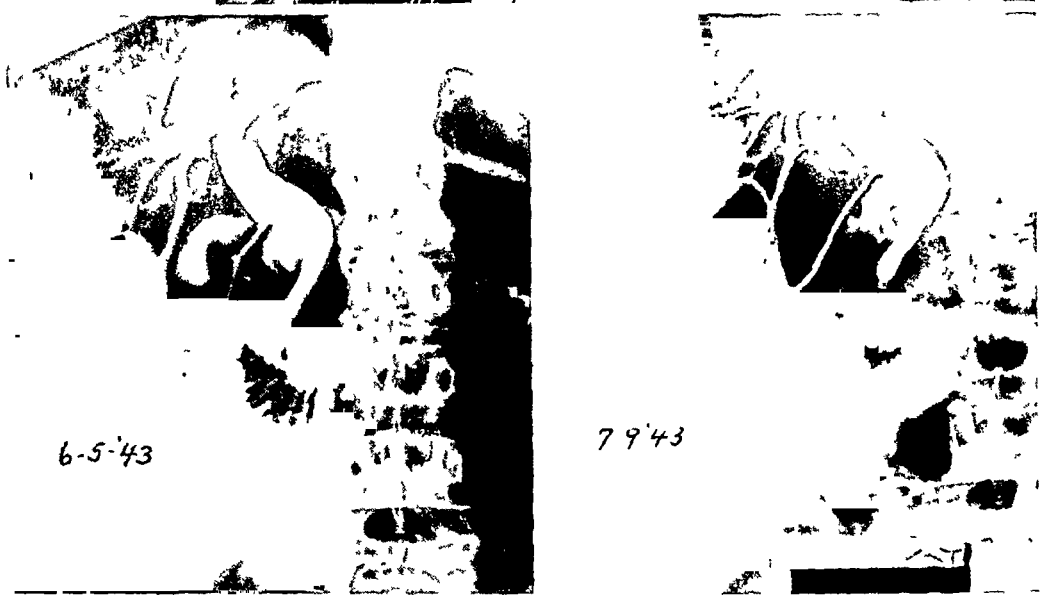




FIG. 2-A

2-B

FIG. 1.—Case 1: Choledochograms ten days after operation showing absence of filling of the distal intrapancreatic portion of the common duct with wide dilatation of the duct proximal to this point. The radiopaque solution passed into the duodenum, indicating incomplete obstruction.

Film B made 30 minutes after film A shows retention of much of the solution, indicative of partial obstruction. Note filling of the distal portion of the pancreatic duct.

FIG 2.—Case 1: Choledochograms 26 and 60 days after operation showing a progressive increase in the extent of filling of the intrapancreatic portion of the common duct, interpreted as release of inflammatory constriction. Note outline of ampulla and juncture with pancreatic duct.

## CASE REPORTS

CASE 1.—V. H., No. 78224, a married housewife, of 34 years, was admitted to the University Hospital, April 13, 1943, complaining of jaundice, generalized pruritis, weakness, anorexia, some epigastric pain and weight-loss of 27 pounds in four months.

During the last three months of her last pregnancy, nine months ago, she had frequent attacks of moderately severe pain in the epigastrium extending around the left costal margin into the back. These attacks came once or twice a week and lasted a few hours. A white liquid oral medication gave relief. Following childbirth, six months prior to admission, these attacks became more frequent.

Two months ago she had several teeth extracted under local anesthesia and on the following day it was noticed by her doctor that she was jaundiced. A few days later she suffered moderately severe pain for three days, again, relieved by a white chalky liquid. Since then she has had no pain but has been deeply jaundiced and has suffered from generalized pruritis. The stools have been clay-colored and the urine dark. Her appetite has been poor and she has lost 27 pounds in four months.

The family and past histories were essentially negative.

Examination revealed a young, intensely jaundiced woman with diffuse excoriations of the skin from scratching. A smooth liver-edge which was only slightly tender was palpable 5 cm. below the costal margin. The laboratory studies on admission were as follows: Blood Kline and Kahn negative; Hb. 11 Gm.; R.B.C. 3,770,000; W.B.C. 5,900, with segs. 56, staffs 7, esinophils 2, lymphocytes 29 and monocytes 5; prothrombin time 24.6 sec. (control 22.2 sec.); icterus index 165; sedimentation rate 47 mm., in one hour; Blood N.P.N. 21.2 mg., hippuric acid 2.3 Gm. excreted as benzoic acid in four hours, serum cholesterol 412 mg. per cent; serum inorganic phosphate 3.4 mg. per cent; phosphatase 5.1 units per 100 cc. of serum; quantitative urobilinogen too weak to match; cephalin flocculation negative; galactose tolerance negative on all specimens during four-hour period; blood amylase 480 units; gastric analysis, with histamine, no free and total acids, four and six; urine, negative except for bile; stools grey (clay-colored).

Roentgenographic studies showed shadows of an enlarged liver and spleen, an indentation of the lesser curvature at the cardia and pylorospasm.

A few days after admission the patient developed thrombophlebitis of the left leg, delaying exploratory operation for three weeks. During this interval the icterus index dropped from 165 to 28, the jaundice diminished perceptibly and bile appeared in the stools for about six days. But during the week prior to operation the stools again became acholic and the icterus index rose to 81.

Exploratory operation was performed just one month after admission. Both lobes of the liver were swollen and the surfaces had a mottled nutmeg appearance. The gallbladder was contracted down to the size of an olive, and its wall was very thick and pale. It contained no stones. The hepatic and common ducts were enormously dilated and the head of the pancreas was at least twice normal size, nodular, firm and fixed. The pancreas was exposed and tissue removed from its surface for frozen section which was reported normal pancreatic tissue.

The common duct was then opened and explored. There escaped considerable thick muddy bile under tension and similar bile was expressed from the gallbladder. A thorough search of the common and hepatic ducts with grasping forceps, scoop and irrigation produced no stones. A small common duct sound passed with some resistance through the sphincter of Oddi into the duodenum.

The opening into the common duct was closed around a T-tube which was brought to the surface through a stab wound. A cigarette drain placed in the lumbar gutter was likewise exteriorized through a stab wound and the abdomen closed.

Since the cause of the obstruction of the common duct was not definitely determined the gallbladder was left *in situ*, for use in anastomosis to the gastro-intestinal tract if a by-pass subsequently became necessary.

Convalescence from operation was uneventful and the jaundice rapidly faded with the icterus index receding to 15 by the end of three weeks. Unfortunately, only the admission determination of blood amylase was obtained.

Choledochographic studies were made on the tenth, 25th and 60th postoperative days (See Figs. 1 and 2). The first choledochograms were interpreted as follows:

"The distal 2 cm. of the common duct show a definite narrowing or constriction. The common duct is dilated proximally up to 2 cm. Diodrast passed into the duodenum and showed a reflux into the pancreatic duct. *Impression:* Constriction of common duct distally and dilatation proximally, which may be associated with pancreatic disease."

The two subsequent studies were interpreted as showing no change except for increased filling of the constricted distal 2 cm. of the common duct.

The T-tube was removed July 9, 1943 approximately nine weeks after operation and after 24 hours no bile drained from the sinus.

The patient has remained well and there has been no return of jaundice in nearly three years.

CASE 2.—No. 162451: J. M., an intensely jaundiced man, age 71, entered the Nebraska Methodist Hospital, July 28, 1945, complaining of weakness, loss of appetite, nausea, epigastric distress described as bloat and burning, jaundice and generalized pruritis of three weeks duration.

Six months previously he had been disabled for a few weeks from contusions inflicted in an automobile accident. He denied having taken any drugs at that time or subsequently.

For one year he had frequently been distressed with a burning sensation and belching following meals which were rich in fats. There had been no other symptoms referrable to gallbladder disease until three weeks before admission. At that time the burning sensation which had been confined previously to the epigastrium extended into the right hypochondrium and into the back and at the onset was accompanied by nausea and vomiting. On the following day his physician observed that he was jaundiced. Subsequently, as the jaundice increased, there developed pruritis, soft clay-colored stools, weakness, loss of appetite and some loss of weight. At no time had he suffered definite pain.

Examination revealed in addition to an intense jaundice with diffuse excoriations of the skin, moderate arteriosclerosis, bradycardia, an hypertension of 160/90 and a smooth slightly tender liver margin about 3 cm. below the costal margin with a mesial rounded mass which was assumed to be a distended gallbladder.

On admission, the urine contained much bile and a trace of albumin; the blood, Hb. 97 per cent, R.B.C. 5,050,000; W.B.C. 11,300, with a normal differential. The blood Kahn, Kline and Mazzini were negative. The prothrombin time was 36 seconds with a normal standard of 12–14 seconds; the icterus index 240 units and the blood amylase 530 units. The stools contained no bile.

A plain roentgenogram of the abdomen revealed no evidence of stones and was negative except for vertebral osteo-arthritis.

A provisional diagnosis of carcinoma of the head of the pancreas or of the ampulla of Vater was made and the patient prepared for operation with parenteral glucose and maximum therapeutic doses of vitamins B complex, C and K. The prothrombin time dropped to 28 seconds.

The cephalin flocculation and galactose tolerance tests done on the day prior to operation were negative.

Operation revealed the liver symmetrically and much enlarged, with a pale mottled appearance. The gallbladder was contracted to the size of a large olive and its wall was very thick. The mass palpated and interpreted preoperatively as an enlarged gallbladder was probably the enlarged left lobe of the liver. The common duct was not much enlarged but had a thick wall and was enclosed in dense fibrous tissue; no

stones or other abnormalities were palpated in it. The head and a portion of the body of the pancreas were definitely enlarged, firm and nodular but no discrete hard masses were palpable. The common duct was opened and a surprisingly small quantity of thick bile escaped. A small amount of similar bile was expressed from the gallbladder. No stones were found in the ducts despite painstaking search with forceps, scoop and lavage. A small sound was passed into the duodenum and the ampulla of Vater felt normal as palpated over the sound.

The opening in the common duct was sutured around a T-tube which was delivered to the surface. Through a stab wound a cigarette drain was placed in Morison's pouch and the abdomen closed.

Because the ducts were only moderately dilated and because there was not a large pool of dammed-back bile to escape upon opening the common duct it was my impression that the patient had a toxic hepatitis or some other intrahepatic type of icterus. However, apprehension in this regard was dispelled by the uninterrupted excretion of bile and the uneventful convalescence.

During the first 24 hours 275 cc. of bile drained through the T-tube and subsequently the daily output varied from 350 cc. to 500 cc. There was a rapid dissipation of the icterus and the patient left the hospital 22 days after operation. At that time the icterus index had dropped from the preoperative level of 240 to 22 units. The blood amylase which rose to 920 units on the second day after operation was still 760 units on the 18th day. These unusual blood amylase findings are reported with reservations regarding accuracy but in prospect of similar findings in similar cases.



FIG. 3.—Case 2: Choledochogram 11 days after operation and 30 minutes after injection of the radiopaque solution. Note lack of filling of the distal end of the common duct with a small quantity of retained solution proximally.

Choledochograms made on the 11th day following operation (Fig. 3) showed that the major portion of the injected iodized oil passed directly into the duodenum with evidence of very little obstruction and no filling defect. The distal common duct failed to fill and there was some retention after 30 minutes.

The T-tube was clamped when the patient left the hospital. Three weeks later his family physician reported that there had been no recurrence of jaundice and upon instruction removed the tube.

The patient remained well and there was no recurrence of jaundice for seven months. He then developed an upper respiratory infection for which he took some "cold tablets."

A few days later he developed jaundice, nausea and acholic stools and after five days entered the hospital intensely jaundiced, with a moderate ascites and in stupor. Before death ensued, 18 hours later, the hippuric acid and cephalin flocculation tests indicated liver failure. The icterus index was 100 units, the prothrombin time 48.5 (control 22) seconds, and the serum amylase 103 units.

The postmortem examination revealed about four liters of bile-stained ascitic fluid, a very small pale yellow liver (820 Gm.) which on section showed necrosis and extensive loss of liver cells with fibrous and fatty replacement. The common bile duct

was normally patent and normal in appearance. It contained no bile and there was no bile in the intrahepatic ductal system. The gallbladder was very small, contracted, thick-walled and contained no bile and no stones. The pancreas was normal except for some fibrosis in the portion of the head immediately underlying a deep posterior duodenal ulcer. There was also an ulcer on the anterior wall and the stomach and small bowel contained much blood which presumably was lost from one of the ulcers. The only additional pertinent finding was some areas of atelectasis and terminal pneumonia in both lungs.

There is unequivocal necropsy evidence that death and the brief terminal episode of jaundice resulted from hepatitis with degeneration of the liver to the point of failure. It was hoped that the necropsy would also establish the cause of the episode of jaundice and acholic stools which seven months previously was cured following drainage of the common duct. Unfortunately, the additional evidence is inconclusive and does not alter the original clinical impression. It dispelled all doubt of an overlooked source of obstruction of the common duct such as stone and neoplasm. The evidence argues strongly that both episodes represented failure of a damaged liver varying only in degree with a brief intervening period of regeneration and recovery. However, it seems inconceivable that a severely damaged liver not only would survive the insult of operation but also would immediately resume normal excretion of bile and rapidly recover, especially in an individual 71 years of age.

There was some postmortem evidence of a preëxisting pancreatitis, the source of which might be explained upon the basis of the overlying posterior duodenal ulcer.

Discussion.—In making the diagnosis of chronic pancreatitis with obstructive jaundice it is assumed that (1) the jaundice is extrahepatic in origin; (2) chronic pancreatitis exists; and (3) the assumed inflammation of the pancreas is capable of obstructing the common duct. In the second case only is there any question that the jaundice was not extrahepatic. It seems probable that the liver damage which caused the second episode of jaundice and death had its origin in the hepatitis which accompanied the period of obstructive jaundice prior to operation seven months previously.

A diagnosis of chronic pancreatitis can be made with certainty only by histologic confirmation. In the living this may be accomplished by biopsy and such confirmation has been reported. A negative biopsy as in my case has no significance because the tissue removed from the surface may be remote from the inflammatory process. Furthermore, the information to be gained from an adequate biopsy does not justify the hazard involved.

The other two sources of information upon which a diagnosis is based are inconclusive. First, the impression of the surgeon as gained from palpation and inspection of the gland is valuable in proportion to the experience of the surgeon and is always subject to the error incident to the wide normal variation in the size and consistency of the pancreas.

The second source, an elevated serum amylase is suggestive if not indicative of inflammation of the pancreas. This has been abundantly investigated and

has been a fairly consistent clinical observation. Furthermore, studies have demonstrated rather consistently that serum amylase is relatively normal in cases of gall-bladder disease with no associated pancreatitis and is usually below normal in cases of hepatitis and other disease of the liver.

Foged, Millbourn, and Branch and Zollinger have found the serum amylase elevated in cases of obstruction of the common duct by a stone at the ampulla of Vater. Lewison suggested that in these cases the common and one of the pancreatic ducts have a common opening at the ampulla so that the stone also obstructs the pancreatic duct. He also observed that serum amylase in these cases is elevated only slightly in comparison with the high levels observed in cases of acute pancreatitis.

In both of my cases the serum amylase attained the high levels which are seldom seen except in cases of acute pancreatitis. For this reason their accuracy and value in these instances are open to question.

The third assumption that the inflamed pancreas in my cases obstructed the distal end of the common duct was suggested by the resistance encountered in passing a bougie. Choledochographic studies in these cases, as illustrated in Figures 1, 2 and 3, are offered as graphic evidence of constriction of the distal or intrapancreatic portion of the common duct.

## CONCLUSIONS

1. Reported are two cases of relatively painless extrahepatic obstructive jaundice. In both cases there was chronic cholecystitis without stones, and much evidence to support a diagnosis of chronic pancreatitis. Both cases recovered following surface drainage of the common duct.

2. In both cases the postoperative choledochograms showed narrowing of the distal end of the common duct suggestive of compression from pancreatic disease. In one case subsequent choledochograms were made and these showed a progressive increase in the filling of the constricted portion of the duct, interpreted as evidence of release of compression.

3. From the evidence it is suggested that the obstruction of the common duct in these two cases probably was caused by chronic pancreatitis. The evidence is offered in support of the hypothesis that on occasion the swelling of chronic pancreatitis obstructs the intrapancreatic portion of the common duct.

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DISCUSSION.—DR. RALPH COLP, New York City: I think the excellent result obtained in this patient following drainage of the common bile duct was due to the relief of the biliary reflux. The roentgenograms show the outline of part of the pancreatic duct and it is possible that the reflux of bile caused the pancreatitis. By relieving pressure by choledochostomy, a marked improvement took place. I recently had occasion to operate upon a patient who had a chronic infection of the gallbladder with stones and, following cholecystectomy, he began to develop attacks of jaundice. Sixteen months later, exploration revealed a marked dilatation of the common bile duct extending into the hepatic duct due to pancreatitis, and I performed choledochoduodenostomy over the tube. Six months later there were recurrent signs of obstructive jaundice of no great intensity, but he was febrile and I felt that reëxploration was indicated. I found an enormous dilatation of the common bile duct, and the pancreas, previously hard and diffusely infiltrated, was still of the same consistency. There was no evidence of carcinoma. I performed a choledochoduodenostomy over the vitallium tube. I was able to pass a probe freely into the common bile duct at the first operation, but at the second operation it was not possible, even though the patient was only mildly jaundiced.

(slides) This shows the presence of the vitallium tube, the funnel part of which is in the common bile duct. This slide shows the marked dilatation of the duct with reflux of barium which had previously been given by mouth. You can see the pancreatic portion of the common bile duct outlined by a very thin stream of barium. I doubt very much whether a choledochostomy would have caused a reversal of the pancreatitis which was present in this case.

DR. JOHN J. MORTON, Rochester, N. Y.: I am a little surprised that Doctor Bisgard found elevated amylase so late in the disease. In the first week the pancreatic amylase will drop to normal if the patient is going to recover, and faster than that in the fulminating hemorrhagic type which destroys the pancreas. Sometimes there is a moderate infection present, and in these cases the amylase steps-up and you have to take out some of the pancreas as there will be a partial pancreatic necrosis. Chronic pancreatitis, according to the literature, is not accompanied by a rise in the blood amylase.

DR. I. S. RAVDIN, Philadelphia, Pa.: I am in hearty agreement with what Doctor Morton has just said. We have never seen elevation of blood amylase concentration such as Doctor Bisgard has reported in chronic pancreatitis. These have always been associated with acute inflammatory reaction. The choleo-angiograms are not unlike some of those I see where I have removed a stone from the lower end of the common duct. Doctor Prendergrass reports this as evidence of reaction in the pancreas, but not as chronic diffuse pancreatitis. In the last slide shown, the hepatic ducts were

still clearly outlined, which means that the impediment to bile flow, whatever it may have been, still persisted. Finally, reflux into the pancreatic duct must be considered as evidence of continuing distal ductal obstruction. If there were no impediment of either the sphincter mechanism or in the ampulla, the pancreatic duct should not be visualized. If these patients did have pancreatitis it was still persisting, and I would not have interpreted the last films as evidence of marked improvement.

DR. J. DEWEY BISGARD, Omaha, Nebr. (closing): In reply to Doctors Colp, Morton, and Ravdin, I might say that I too questioned the validity of the high values of the blood amylase in these cases. The values in other cases have always been in line and usually normal values.

In one case the blood amylase went up to 920 units following operation and was still 760 units on the 18th postoperative day. This was added reason to be critical of the laboratory, but on their record I accepted the figures and recorded them in this report. Going through the literature, I found records of similar elevation of the blood amylase in cases in which the common duct was obstructed by a stone lodged at the ampulla. It was suggested that in these cases the stone also obstructed the pancreatic duct. In most cases of stone in the common duct, however, there is no appreciable rise in the blood amylase, and in liver disease there is an actual decrease.

The fact that the jaundice did clear in these two cases and remained so after the T-tubes were removed was evidence that whatever caused the obstructive jaundice had been released and, as stated in the paper, it is difficult or impossible to exclude some obstructing factor other than pancreatitis that might have been dislodged at operation. A roentgenologist, with a very wide experience in interpreting choledochograms, interpreted the defect in the distal end of the common duct, in the films shown, as a defect caused by pancreatic disease. I routinely do postoperative choledochograms on all cases in which I have opened the common duct, and I have yet to see a constriction of the distal two centimeters, or so, of the common duct as shown in these slides. I am rather surprised to hear Doctor Ravdin interpret this constriction as spasm of the common duct. To my knowledge the common duct contains no muscle and, without muscle, spasm is impossible.

# RESULTS FROM USING VITALLIUM TUBES IN BILIARY SURGERY*

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ANY SURGEON who has treated extensive injury of the common bile duct is well aware of the tendency to recurrent stricture formation with jaundice, cholangitis, and liver damage. These strictures do not respond, as do some smaller ones, to dilatation, plastic repair, or excision with end-to-end anastomosis of the duct. Attempts to implant a biliary fistula failed. Anastomosis of the bile duct to the duodenum was done, but the results were poor, for in Eliot's[8] review of 68 cases, only 16 (23 per cent) were successful.

Badly damaged or excised bile ducts were repaired by end-to-end anastomosis over a Vitallium† tube, hoping in this way to preserve their continuity and to prevent reformation of the stricture. This was first done on February 26, 1940, the method was reported[17, 18] and the tubes were made available for the use of other surgeons. I was only interested in their design, so the manufacture, distribution, and sale were carried on by the Austenal Laboratories, makers of Vitallium, who have marketed the tubes through surgical instrument dealers. Thus, there was no way of my knowing who had used them and what the results had been. It was decided to write the members of the American Surgical Association, not only to seek their experience, but also to ask the names of any other surgeons that they might have known who had used the tubes. The response was very gratifying, for, with but few exceptions, replies were received and necessary data given in spite of the press of extra work both in civil and military life due to the war. I am very grateful for this.

The data received combined with that from personal experience allowed the study of 229 cases. Of these, 13 were excluded because they did not give the information pertinent to this study. In ten of these the patient died in the hospital soon after operation, and in three cases it was found that the tube had not been placed in the bile ducts.

## REPAIR OF THE COMMON BILE DUCT

There were 106 cases in which a Vitallium tube was used to repair a damaged or excised common bile duct. Some of these were very extensive injuries involving loss from just below the bifurcation of the hepatic ducts to just above the pancreas. The results are shown in Table I.

In such a serious condition often preceded by multiple operations where the best previous score was 23 per cent[8] this figure of 80.1 per cent good results is encouraging. It will be noted that one cause of failure was from bridging a gap with the tube by tying its ends into the ends of the bile duct. These

*Read before the American Surgical Association, April 2-4, 1946, Hot Springs, Virginia.

† "The word Vitallium is a registered trade-mark of Austenal Laboratories, Inc."

cases failed, for sooner or later the tube slipped. Bridging a gap is unnecessary, for even with wide separation it is possible to mobilize the duodenum and pancreas and suture the ends of the duct together over the tube. Final success depends upon accurate end-to-end anastomosis even if done under some tension. The tube holds this open and prevents stricture during healing.

TABLE I

RESULTS FROM USING A VITALLIUM TUBE IN 106 CASES OF REPAIR OF THE COMMON DUCT

| | |
|---|---|
| Good | 83 cases |
| Good, but tube passed | 2 cases |
| Total—good results | 85 cases—80.1% |
| Doubtful | 1 case |
| Poor—tube plugged | 12 cases—11.3% |
| Poor—bridged a gap | 7 cases |
| Poor—tube slipped | 1 case |
| Total | 106 cases |

The finding of poor results in 12 cases (11.3 per cent) due to plugging of the tube is more disturbing, for it is not so easily remedied. Many of these patients have infection which increases the tendency to deposition of sediment. I have had this material analyzed on three occasions through the coöperation of Drs. S. H. Bassett and H. E. VanAlstyne.

| | | |
|---|---|---|
| January 21, 1944 | Lipids (cholesterol) | 0.1664 Gm. (38%) |
| | Insoluble* | 0.2655 Gm. |
| March 24, 1945 | Lipids (cholesterol) | 0.1619 Gm. (36%) |
| | Insoluble* | 0.2881 Gm. |
| October 23, 1945 | Lipids (cholesterol) | 0.146 Gm. (56%) |
| | Insoluble* | 0.114 Gm. |

* Only from 0.0015 Gm. to 0.0075 Gm. of calcium could be extracted from the insoluble fraction. The remainder appeared to be bile pigment.

This level (36 per cent-56 per cent) of cholesterol is disappointing for it is the only soluble constituent. It has been our custom to give sodium taurocholate at intervals postoperatively in the belief that the solubility of cholesterol was increased. Sodium dehydrocholate also does this, but ox bile (U.S.P. 45 per cent cholic acid) is not so effective.

My personal experience with plugging of the tube has turned out fortunately, for information of value has been obtained. It was found that there had been restoration of normal mucosa, appearance and caliber, so the plugged tubes were removed and the ducts closed.

## CASE REPORTS

Case 1.—No. 171848: E. H., a 54-year-old diabetic female. First operation elsewhere, May 22, 1940, for acute cholecystitis. Jaundice, chills, and fever developed in three months. Second operation, May 29, 1941, dilatation of stricture of bile duct and removal of stones. Jaundice returned in three months. Third operation, October 1, 1941, I found a

stricture of the common hepatic duct about 1.5 cm. long that was "so dense that the smallest probe had to be forced through it." Stricture excised and duct sutured over a Vitallium tube with relief for over two years, when jaundice returned. Fourth operation, December 24, 1943. The plugged Vitallium tube was removed. "To the operator's amazement, it was found that the duct would admit a No. 18 catheter easily, and that the lining of the duct was smooth, velvety mucosa which was perfectly normal in appearance." The opening in the duct was closed and uneventful recovery followed. Last follow-up on January 31, 1946 (25 months postoperatively) "The patient's condition is excellent."

Case 2.—No. 186570: A. B., a 33-year-old female had a cholecystectomy elsewhere, November 11, 1941, at which time hemorrhage occurred and the bile duct was opened. It was drained. She had attacks of pain and jaundice after operation. At the second operation, January 22, 1942, the hepatic duct, just below the bifurcation, entered an extrabiliary cavity that connected with the stump of the common duct which was present for one-half-inch above the pancreas. These ducts were freshened and sutured end-to-end over a Vitallium tube. Her condition was satisfactory until August, 1945, when pain and jaundice returned. The third operation was done, October 10, 1945, to remove a plugged Vitallium tube. The site of the anastomosis was covered with mucosa and admitted a 7-mm. dilator so the opening in the duct was sutured and a cigarette drain was placed in the subhepatic space. One episode of upper abdominal pain without jaundice occurred two months postoperatively, the cause of which was not determined. Since then she has remained well.

This is a very encouraging result, for if a severely damaged duct will reconstitute a normal caliber and mucosa, it will not matter if some tubes plug. They will have served their purpose.

The most trying technical problem in the secondary repair of a severed duct is to find the lower end after it has retracted and become buried in scar tissue. Lahey[11] has described a method of doing this by mobilizing the duodenum and locating the lower end of the common duct on the undersurface of the pancreas. This maneuver permitted identification of the duct in one of my cases. In all the others it could not be found in this way and was only located by careful, patient dissection in the scar just above the duodenum. But dissection in this region may jeopardize the portal vein, and in two cases I have entered this vessel, fortunately with successful suture in each.

In the hope of getting more exact information on how to locate the distal end of the duct, 18 cadavers were dissected, with the assistance of Dr. C. E. Tobin, of the Department of Anatomy. In all 18 subjects the lower end of the common duct was imbedded in the pancreas so it could not be identified by looking on the undersurface of that organ. Measurements were taken from the pylorus to the opening of the common bile duct into the duodenum. These ranged from 6.5 cm. to 12 cm. with an average of 8.5 cm., so one cannot locate the duodenal end by measurement. The papilla of Vater was present in ten, small in five, and absent in three. The mucosal fold indicating the papilla was normal in 14, small in two, and absent in two. So by opening the duodenum one is not certain of being able to locate the duct, and may incur the danger of a duodenal fistula.

At the present time a combination of these methods is used. All adhesions are freed from the right lobe of the liver, and the relationship of the duodenum to the foramen of Winslow is restored. The hepatic duct is located. If the

lower end of the duct is not seen, it is searched for in the scar of the gastro-hepatic omentum near the upper border of the duodenum. This relationship with the duodenum at about the junction of the first and second portion is a fairly constant one. If these efforts fail, the duodenum is mobilized and the posterior surface of the pancreas inspected. If the duct is not found either the duodenum is opened or the search is abandoned and the upper part of the duct is anastomosed to the jejunum.

### HEPATICODUODENOSTOMY

The operation of anastomosis of the hepatic or common bile duct to the duodenum, as it was described by Mayo,[15] was probably the most commonly used procedure in this field. It has the two serious disadvantages of allowing reflux of food into the biliary passages, and a tendency to stricture at the site of union. As a consequence, the majority (77 per cent) of the patients have trouble from cholangitis or biliary obstruction. One personal case (No. 227212) has had 16 hospital admissions and ten operations, many as a result of an hepaticoduodenostomy. She was immediately relieved after this was disconnected and the common bile duct was reconstituted over a Vitallium tube. Neither in this case, nor in any other, has disuse atrophy of the functionless distal end of the common duct been found, as reported by Allen.[1]

There are reports of 79 cases in which a Vitallium tube was used in doing an hepaticoduodenostomy. The results are given in Table II.

TABLE II

RESULTS IN 79 CASES OF HEPATICODUODENOSTOMY DONE WITH A VITALLIUM TUBE

| | |
|---|---|
| Good | 43 cases |
| Good, but tube passed | 3 cases |
| Total good results | 46 cases—58.2% |
| Doubtful | 1 case |
| Poor—tube passed | 27 cases—34.1% |
| Poor—tube plugged | 4 cases |
| Poor—fatal hemorrhage from tube | 1 case |
| Total | 79 cases |

If the three satisfactory cases in which the tube passed are added to the 27 poor results in which it passed, it is seen that in 30 cases (38 per cent) the tube is known to have passed into the gastro-intestinal tract. It is probable that, in the end, the majority will pass, for there is little to prevent it. Certainly, the flange in the center is not enough, nor are sutures, for all past experience indicates that any foreign body that protrudes into the bowel will eventually be passed.

These Vitallium tubes were never designed for hepaticoduodenostomy; in fact, they were designed to avoid it, and to retain the function of the sphincter of Oddi by reconstructing the bile duct. But soon after they were available surgeons used them in the duct-duodenal anastomosis, so this use was illustrated[18] in their description. Perhaps this was unwise, for it may have contributed somewhat to having 79 cases of this type to report here. Granted

that the operation is an expedient way out of a difficulty that may give brilliant immediate results, yet it is essentially unphysiologic. The use of the vitallium tube cannot alter this, for it can only prevent stricture of the anastomosis. Reflux and the threat of cholangitis will remain.

### HEPATICOJEJUNOSTOMY

As a general principle a bile duct without a sphincter should not be connected with a loop of intestine that conveys food, for sooner or later this will cause trouble. An antiperistaltic loop of jejunum fulfills this requirement. Antiperistalsis has been shown by Mall[13] to be capable of causing partial blockage of the intestinal current. It has been employed by Mann[14] to prevent leakage from intestinal fistulae. Whipple[22] used the Roux-Y-type of antiperistaltic loop of jejunum to anastomose to the biliary tract after resecting the head of the pancreas.

In this series there were 18 cases of hepaticojejunostomy done with a Vitallium tube, the results of which are shown in Table III.

TABLE III

*RESULTS IN 18 CASES OF HEPATICOJEJUNOSTOMY DONE WITH A VITALLIUM TUBE*

| | | |
|---|---|---|
| Roux—Y anastomosis—results good | 8 cases | |
| Loop with entero-anastomosis—results good | 7 cases | |
| Total | 15 cases | 83.3% |
| Loop with entero-anastomosis—results poor | 3 cases | |
| Total | 18 cases | |

In seven cases (38.8%) the tube is known to have passed

This group is too small to have any statistical significance, but the facts available would indicate that the results are superior to those in hepaticoduodenostomy, which is to be expected. These data also give preference to the Roux-Y-type of anastomosis. In this regard Cole[5] reports a case who after an hepaticojejunostomy by a loop with entero-anastomosis had severe cholangitis. He reasoned that food was being carried past the entero-anastomosis up the proximal loop to the bile duct. So he divided and closed this proximal loop, leaving essentially a Roux-Y anastomosis, with immediate relief of symptoms.

It might be argued that a Vitallium tube is not necessary in doing a bile duct-jejunal anastomosis. This is valid in cases where sufficient hepatic duct remains to do an exact approximation of the structures. However, Cole[6] feels that his results with the Vitallium tube are definitely superior to those without it. In some cases no mobile bile duct is available for anastomosis, and only a hole in the porta hepatis communicates with the biliary tract. Here the insertion of a tube materially helps in the anastomosis.

### OTHER USES

There are three cases where the bile duct was anastomosed to the stomach by means of a tube, with satisfactory results to date. In two instances of

severe chronic pancreatitis a long tube was passed into the duodenum. Both of these were relieved of their symptoms. Five cases of inoperable carcinoma were treated palliatively by using a Vitallium tube, with temporary relief of their biliary obstruction. The pancreatic duct was anastomosed to the intestine by means of a tube in three cases, with satisfactory results.

## SUMMARY

A group of 229 cases were collected, of which 216 were suitable to study the results obtained from using Vitallium tubes in biliary surgery.

1. In 106 cases the tube was used to reconstruct the bile duct and preserve its continuity.
   (a.) 85 cases (80.1 per cent) had good results.
   (b.) 12 cases failed because of plugging of the tube, so the prevention of this is discussed.
   (c.) 7 cases had the tube used to bridge a gap between the ends of the divided duct. All were failures.
2. In 79 cases a Vitallium tube was used in hepaticoduodenostomy.
   (a.) 46 cases (58.2 per cent) had good results.
   (b.) 30 cases (38 per cent) are known to have passed the tube.
3. In 18 cases an hepaticojejunostomy was done using a Vitallium tube. This group is too small for statistical significance, but the results are suggestive.
   (a.) 15 cases (83.3 per cent) had a good result.
   (b.) 7 cases (38.8 per cent) have passed the tube.
   (c.) The Roux-Y appears better than the loop with entero-anastomosis, since all the failures were in the latter.
4. Vitallium tubes were also used in hepaticogastrostomy, in chronic pancreatitis, in inoperable carcinoma, and in pancreatic fistulae.
5. The Vitallium tube has allowed reconstruction of otherwise irreparably damaged bile ducts. This restores the normal anatomic channel. When the lower end of the common duct cannot be found or for any other reason this repair is not feasible, a Roux-Y anastomosis with hepaticojejunostomy appears to be the best substitute.

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DISCUSSION.—DR. I. S. RADVIN, Philadelphia, Pa.: I think Doctor Pearse is to be congratulated for the excellent compilation and presentation he has made. The field is a very difficult one; as Doctor Lahey said some time ago, we would not have so many of these cases if the surgery of this area were done by surgeons competent to do it. There is no method, vitallium tubes, T-tubes, or catheters, or any other, which is suitable for all defects of the common duct and the hepatic duct. Doctor Pearse has pointed out two important features in this type of work. First, it is important to find both ends of the duct. All too frequently the lower end of the duct is not found and attempts are made to bridge the defect, when a more thorough search would have made permanent restoration more likely. The second matter is equally important; one must have mucosa-to-mucosa approximation. If this can be obtained a successful end-result is more likely. It may be better to do this anastomosis over a T-tube; it may be well to do it over a vitallium tube, or over an ordinary catheter, but the important thing is that we get mucosal junction. When we have used a T-tube, we have at times left it in for eight to thirteen months.

We have carried out in eight patients a method reported before this Association many years ago by John Speese, known as the Speese-Ginsberg procedure, and have had several very satisfactory results in the presence of massive defects.

DR. FRANK H. LAHEY, Boston, Mass.: It seems quite natural for me to be discussing strictures of the common duct on this platform because just four months ago on this very platform I discussed strictures of the common and hepatic ducts before the Southern Surgical Society.

It is impossible to report comparably on strictures of the bile ducts because in every group reported there are so many variables. If we were to talk about strictures of the common duct they would in our experience—and we have now operated upon 154 strictures of the common duct—be in the minority. Most of the strictures of the bile ducts that we have to deal with are the result of surgical accidents involving cystic or hepatic artery hemorrhage or difficulties with the junction of the cystic, common and hepatic ducts, and so the strictures in most of these cases involve the hepatic duct alone or the upper common and lower hepatic ducts. Many of the patients with strictures with which we have dealt have been operated upon several times, with the result that there is literally no hepatic duct left, and the only hepatic ducts which can be obtained are those which can be dissected out of the hilum of the liver by means of a fulgurating current. In not a few of these cases all of the hepatic duct has been destroyed and there remain only the left and right branches to which Y-tubes must be placed. This is why it is so difficult to report comparable end-results in these cases.

We have implanted 41 vitallium tubes. I have little faith in them. I think we have been under a misapprehension regarding them. We are, I believe, inclined to think of vitallium tubes as satisfactory structures because they are so well-tolerated by the tissues. The important thing in my opinion is not how well they are tolerated by the tissues but whether or not they plug any less often than do other types of tubes. I do not think they do. We have had a number of the vitallium tubes become completely occluded with biliary detritus, have had to take them out, replant other tubes and have them again plug. We had one case in which I implanted a rubber tube over a defect at least two and one-half inches long. This patient recently died at the end of eight years, never having been jaundiced at any time during the eight years, having lived quite comfortably, and yet at autopsy the rubber tube, which I have, was completely plugged and probably had been plugged for a great many years. All his bile had undoubtedly passed around the tube.

There is a material which I have employed which has all the advantages of a rubber tube and many advantages over vitallium tubes. It is a material called "bouncing clay," which we have obtained from the experimental laboratory of the General Electric Company. It is flexible, it will stretch, it will bounce like rubber and it can be cast in any shape. I am sure it has no advantages as to whether or not it will plug over either plain rubber or vitallium tubes. It does, however, have the great advantage in that it can be cast in any shape, that its flexibility permits its introduction into the devious channels which one often meets in strictures of the bile ducts, and that it is easily handled. My own feeling about vitallium tubes is that unless they possess greater likelihood of not plugging than do flexible tubes, their rigidity makes them not only difficult to introduce but at times dangerous because of the possibility of hemorrhage from pressure erosion.

We have learned that in most strictures of the duct the lowest portion of the common duct within the pancreas is intact. We have learned by splitting the lower end of the pancreas to find the common duct here and to demonstrate it well down to the point where it enters the duodenum. We have also learned that it is possible to so mobilize the duodenum that with this demonstrated portion of the duct, end-to-end anastomoses over tubes can frequently be accomplished.

I have just sent home a patient with a perfect intraductal anastomosis in whom, because of dilated hepatic and dilated common ducts with a stricture between the two, an accurate mucosa-to-mucosa anastomosis could be done within the duct.

Concerning the introduction of T-tubes, in articles on this subject some time ago, I proposed that the T-tube be introduced through a separate incision above the stricture and the suture line of the mucosa-to-mucosa anastomosis, in order that when it was withdrawn there would not be interference with the suture line. I feel sure that tubes can permanently be taken out when good mucosa-to-mucosa anastomoses

can be accomplished but when a defect occurs between mucosa and mucosa and scar tissue exists over any considerable area, contraction will eventually occur unless a permanent indwelling tube is left in position.

Strictures of the common and hepatic ducts are surgical catastrophes. The ultimate result in most cases, particularly in those in which repeated operations have been done, will not be satisfactory. We would not have these strictures if we had wide incisions, good exposure, good relaxation, and if it could be realized that while most gallbladder surgery is relatively simple, occasional cases occur which will tax the skill and resources of the most experienced surgeon.

I wrote an editorial on strictures of the common duct which I thought would cause considerable criticism. I think it should be repeated. It is to the effect that if a man injures the common and hepatic ducts during a cholecystectomy, he should seriously consider whether or not he has had enough experience to attempt to repair it. Agreement should be almost universal with the point of view that if a man has injured a common or hepatic duct and then has unsuccessfully attempted to repair it, he should not attempt it again, and this could go on almost indefinitely because we have operated upon these cases in which four or five attempts have been made to repair an injured duct. It should be remembered that the surgeon who has the first chance to repair the ducts after injury has the greatest opportunity of getting the best results, that with each repair there is loss of substance in the duct, a greater amount of scarring and less chance of a good result. It is for this reason that I have pleaded that these patients be sent to men who have been interested in and have had experience with the repair of strictures of the common duct.

One could rightly look with suspicion on this statement were it not true that in Boston, in New York, and in almost every part of the country there are men who have published articles on this subject and who have been interested in it, and for this reason I make this statement without fear of being suspected of any selfish interest.

DR. WALTMAN WALTERS, Rochester, Minn.: I think Doctor Pearse is to be congratulated for assembling the data contributed by members of our Association. One or two points should be stressed. The postoperative result is determined not alone by the accuracy of the anastomosis of the cut end of the common or hepatic duct to the opening made in the intestine, but also by the degree of infection in the wall of the duct as well as in the liver. It is quite possible to perform an accurate anastomosis between the end of the duct and the duodenum or a loop of jejunum and still have intrahepatic infection or secondary obstruction at the anastomosis.

Then the question arises of how to maintain a foreign body, such as a tube, in the duct at the site of the anastomosis. Perhaps you may remember McArthur's description of a method for anchoring a catheter in the common duct by passing a long silk suture through it. He brought this suture out of the incision and anchored it to the abdominal wall. I have used this method in many cases, and it is possible by this means to maintain a catheter at the site of the anastomosis of the hepatic duct to the duodenum for many months, even though there is intermittent peristalsis which tends to cause it to become displaced.

About the vitallium tube, I agree with Doctor Pearse, Doctor Lahey and Doctor Ravdin, and have to add only that it is a rigid tube. Its lumen may become obstructed by bile pigment and débris, whereas a rubber or plastic tube is probably elastic. Any tube at the anastomosis serves two purposes; one is to transmit bile; and the second is to serve as a splint during healing and to prevent contractures. Sir Harold Stiles and McIndoe have expressed the opinion that it is necessary to maintain a scaffolding for about three months to prevent contracture at the site of a plastic procedure for the maintenance of a lumen, be it at the ureteropelvic juncture, in the urethra or the vagina. I believe that such a principle may apply in certain, but not

all, cases in which anastomosis is made between the common duct and the intestine. Some of the best results I have had in the performance of plastic operations for relief of obstructions of the biliary and genito-urinary tracts have been obtained when I did not use tubes or catheters of any type.

I did not use a vitallium tube before 1942, but then I thought I would try one in one case, and it worked satisfactorily. I passed the silk suture through a hole in the flange and carried it through the incision, where it was maintained in place with a button attached to the abdominal wall by means of adhesive tape.

In Doctor Pearse's first case a vitallium tube was removed two years after its insertion in the common duct and, when it was removed, the anastomosis was in excellent condition and without evidence of contracture. This observation is important in evaluating results. McArthur, employing the catheter method, reported good results in, I think, six or nine cases in which end-to-end anastomosis of the duct was made after excision of the stricture.

The results reported by members of the Association in treatment of this serious lesion are a great credit to the medical profession. The risk of the operation is high; the patients are in poor condition and damage to the liver is extensive. It seems to me it is important to emphasize the good results obtained in more than 50 per cent of the cases whenever the problem of recurrent stasis at the anastomosis is discussed.

In the treatment of stricture of the common duct the type of case in which a stricture is localized to a small portion of the common duct does not present the most difficult problem; but the case in which there is no extrahepatic duct does. In the latter type of case the greatest ingenuity is required to relieve obstruction and either to maintain a channel to the exterior or to produce an internal fistula. An aspirating needle inserted into the liver at the hilus usually will assist the surgeon in finding an intrahepatic duct. A catheter placed in this will relieve biliary obstruction and, in an occasional case, will produce pressure necrosis of the anterior wall of the duodenum, with the establishment of an internal fistula between the intrahepatic tract and the duodenum. I have had two cases in which such a passage has been maintained by keeping a urethral catheter in the sinus. I think we surgeons should keep on working to see what additional improvements can be developed in the management of these cases of stricture of the common and hepatic ducts.

DR. HERMAN E. PEARSE, Rochester, N. Y. (closing): I wish to thank those who discussed the paper. It is a well-known fact that when many different methods are devised for the same purpose, none are completely satisfactory. I hold no brief for vitallium, but so far as I can determine it is best tolerated of any foreign substance. Its disadvantage is that it is hard and unyielding and cannot be shaped or adjusted to meet the needs of every situation. Tantalum is more malleable but cannot be welded, so no anchoring flange can be attached to the tube. Rubber has a thicker wall and hence a smaller lumen. It was my dissatisfaction with the irritation and fibrosis caused by rubber that led me to use vitallium in the first place. Most plastics are phenolized resins, and may be irritating to tissues. Unfortunately, the common duct of animals repairs with such ease that it is not suitable to test different methods, so I fear we must continue to assess our results on human beings. I doubt if in the end any one method will always prove to be the best for, as Doctor Lahey says, circumstances in individual cases vary so markedly.

# TETANUS—A PREVENTABLE DISEASE*

## INCLUDING AN EXPERIENCE WITH CIVILIAN CASUALTIES IN THE BATTLE FOR MANILA (1945)

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BECAUSE of its dramatic manifestations, tetanus, one of the horrors of war, has been well recorded for centuries. In the Civil War[1] (1861-65), among 246,172 wounded there was an incidence of 2.07 per thousand. The disease has had a high mortality rate that has not been notably reduced. The progress in combatting tetanus since the causative organism was demonstrated between 1884 and 1890 has rested in its prevention and not its treatment. After the introduction of antitoxin during World War I (1914-18), the British[2] reported an incidence of 0.015 per thousand in 2,032,142 wounded, and the American troops[3] during the same war reported 0.016 per thousand among 224,089. Antitoxin provided a passive immunity when used prophylactically. An active immunity to tetanus was demonstrated to be produced by tetanus toxoid in 1921, shortly after World War I by the French Army.[4] In 1930, a tetanus toxoid was produced in the United States[5] capable of inducing a high antigenic titre which has since been used to protect all American soldiers against tetanus. In this war the use of tetanus toxoid has been, beyond all doubt, one of the most successful projects in preventive medicine. The absence of the disease is spectacular only by contrast. That there had been no clinical tetanus in American troops throughout the SWPA in the war attracted little attention until approximately 500 cases of tetanus developed among the civilian battle casualties in the battle for the capital city of the Philippines.

The fighting in and about Manila was intense and bitter throughout the month of February but had largely subsided by the latter part of March. The American soldiers who were engaged in this struggle had in common with the civilian population the general surroundings with the same bacterial flora and sustained similar wounds, and yet they escaped without a single instance of tetanus.

As Surgical Consultant of the Sixth Army, I had an opportunity to observe many of the civilian wounded in Manila. The medical importance of the high incidence and severity of tetanus then appearing was evident early and the collection of information and data about such patients was begun. The civilian hospitals operating under combat and siege conditions which prevented the preparation and accumulation of detailed records were

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

aided by Army personnel, and in one instance the San Lazaro Hospital was operated directly by representatives of the Surgeon of the Sixth Army for a few weeks after American troops entered Manila. The account of the observations concerning the care of civilian battle casualties who developed tetanus represents information collected from all possible sources.

In order that the unusual background that provided such optimum conditions for the development of tetanus may be kept in mind, it is necessary to review some of the circumstances then existing. A city that is held and defended by one military force and attacked by another from the air and ground as well as by a not far off naval force soon becomes a place where the care of the wounded and sick is difficult indeed. Manila was such a place in February and March of 1945. The inhabitants could not flee the city; they were subjected to the action of Japanese military force as well as to the fire from the American elements besieging the city. The civilian population for long had been on a limited diet, and this was markedly curtailed with the onset of active fighting. The wounded accumulated from air bombing, artillery fire and small arms, hand grenades and bayonets and swords of the Japanese. The casualties were taken by relatives, friends, or bystanders to the hospitals. These institutions were also casualties — some had sustained direct hits; personnel had been depleted by enemy action in some instances, by urgent demands to administer to those outside the hospitals; some in attempting to protect their families had been cut off from returning, others had been commandeered by the Japanese. The result was that only a token number of the hospital personnel were in these hospitals, and under the prevailing confusion organization did not exist. The water supply was early cut off, the sewage systems became blocked, and the food supply was further limited, as it had been for some time before, and very quickly became almost negligible. The civilian hospitals were overfilled with the wounded, the dying, and the dead.

In the San Lazaro Hospital a few days after the beginning of the battle for Manila there were approximately 1,300 civilian patients, and over 1,100 of these had been wounded. One hundred and fifty-six cases of tetanus developed from this group. The picture of this hospital was a most unhappy one — it was overcrowded, all beds and all floor space were filled with the wounded, many dying, many dead. By and large, the dead had the most severe wounds of the head, thorax, and abdomen. However, among the living there were wounds of every part, approximately 70 per cent involving one or more of the extremities. An occasional wound had been closed but the majority had had no surgical care. Some wounds were covered with dressings of sorts consisting of parts of clothing. Bandages were few and flies swarmed over the partially exposed wounds. Fractures of the extremities were splinted for the most part only by the pain that prevented patients from moving. The patients, children and adults, exhibited all phases of injury, exsanguination, shock, infection, and malnutrition.

The location of wounds in the 156 patients who developed tetanus was as follows:

| | |
|---|---|
| Head and face | 20 |
| Neck | 1 |
| Thorax | 12 |
| Abdomen and back | 17 |
| Buttocks | 21 |
| Pelvis | 4 |
| Upper extremities | 34 |
| Lower extremities | 76 |
| Burns and miscellaneous | 21 |

There were many instances of multiple wounds. The number of patients with wounds of the head and neck who developed tetanus was small in comparison to those with wounds in other regions of the body. Compound comminuted fractures of the long bones associated with massive soft-tissue damage and extensive infection, on the other hand, seemed to be the type of wound most frequently associated with tetanus. Dependable and accurate data were seldom available as to the exact time of wounding and the onset of the symptoms of tetanus. It can be said with certainty that there were instances of tetanus being evident as early as three days and as late as 20 days from the date of injury. It may be estimated that 60 per cent of the patients who developed unmistakable evidence of tetanus did so within seven days.

The onset of symptoms was difficult to evaluate because of the general poor condition of these patients as described above. The vital processes were so depressed in the group and the clinical pictures so complicated by coexisting abnormal states and infections that they masked the classical early manifestations of the disease, such as the complaint of headache, stiffness of the neck muscles, and difficulty in chewing. Locked jaws were all too evident when fully developed, as were tetanic seizures and opisthotonos, and yet often these were the first manifestations of the disease to be observed. It should be stressed that the complaint of headache, stiffness of muscles, and pain in the region of the wounds could be elicited from the majority of the wounded.

Local tetanus was observed in the region of wounds and also in muscle groups proximal to the wound as well as the muscles of the entire extremity. Severe local tetanus associated with mild general tetanus was not uncommon, and muscle spasm both tonic and clonic was marked in the extremity where the wound was located. Usually the wound was located in the distal portion, as on the forearm or hand of the upper extremity and leg or foot of the lower extremity. Local tetanus involving an extremity independent of the wound was not seen. However, one patient developed local tetanus in the stump of a midthigh amputation following removal of a gangrenous leg, the result of a compound fracture of the distal portion of the femur. Tetanus was not observed before the operation and local tetanus was present on the following day. It persisted for almost two weeks and subsided. During this period there was a slight trismus and almost no stiffness of the neck muscles.

The most frequently observed clinical picture was as follows: A patient with a wound of considerable extent in an extremity from 5–7 days after injury would be unable to open his mouth. There would be marked trismus and stiffness of the neck muscles. Associated with these two findings there would exist, or soon follow, mild spasms which fixed the head, body, and extremities in a straight line — orthotonos. Within a matter of hours as the seizures became more pronounced and more frequent, opisthotonos developed with greater involvement of the back muscles, so that during a spasm the back became arched and the body was truly supported by the head and heels. Concomitantly, there would appear the classical risus sardonicus with elevation of the eyebrows and retraction of the corners of the mouth, producing a grimace that exposed the locked jaws. Orthotonos was observed to be followed not only by opisthotonos but emphrosthotonos. Spasm and rigidity of the abdominal muscles was an early and common finding that preceded generalized seizures and persisted during and between them. As spasms became more intense over a period of hours or days they rendered breathing difficult. With the muscles of the neck and diaphragm and the intercostals in spasm, the air exchange was so reduced that the lips and nail-beds became very cyanotic. During the severe spasms there was profuse perspiration, and pain was excruciating and unbearable. As the disease progressed and the spasms increased in severity and frequency, the patient became physically exhausted but remained mentally clear and terrified. An occasional patient died during a spasm, but the majority following complete exhaustion became listless, and the diminishing convulsive seizures were followed by death.

Dysphagia was common and present in about 75 per cent of all patients with tetanus, whereas trismus was more constant. A few (four) patients with a rapidly fulminating type of the disease did not exhibit trismus. The forearms and hands in the majority of tetanus patients were, in general, spared to a remarkable degree, so much so that even those with the most severe spasm could grasp the sides of the bed or cot during seizures.

The deep reflexes were early exaggerated, and the Babinski reflex was positive in approximately 20 per cent of new cases. Ptosis of the eyelids was observed in seven instances in the 156 patients. Facial paralysis was seen only once and no history could be obtained as to whether or not this was present before the onset of the disease. True cephalic tetanus as described in the literature was not observed. Extensor responses of the foot and leg on stimulation or during a convulsive seizure were common.

Those patients with generalized tetanus exhibited various degrees of urinary retention and without exception had difficulty in urinating. During a spasm urine would be expelled in small amounts. Although a spastic vesical sphincter has been the cause commonly ascribed to this, no difficulty was encountered in catheterizing men or women. Spasm of the rectal sphincter was readily demonstrated early in generalized tetanus. Fecal impactions were rarely seen because the food intake of most of the patients had for some time been negligible.

The great variation of extent and severity of the wounds in such a group of civilian battle casualties with little or no previous primary surgical treatment offered some opportunity to evaluate late operative therapy. Those patients with well-established tetanus who could withstand operation, although improved by such therapy so far as sepsis and general condition were concerned, seemed to follow the common pattern of the disease and with or without specific therapy died. The incision and drainage of grossly infected wounds, the removal of foreign bodies and the accompanying manipulation, on the other hand, did not appear to increase the progress or severity of the disease. Furthermore, guillotine amputation for extensive injuries of the extremities sometimes associated with gangrene and *Cl. welchii* infection did not appear to alter the course. However, it was significant that in the group of almost 40 patients in the San Lazaro Hospital upon whom amputations were performed and who had no evidence of tetanus at the time of operation and no other wounds, only three developed tetanus; two of these died and one ran a course of two weeks and eventually recovered. As previously stated, extensive wounds of the extremities involving deep structures accounted for the greater number of patients with tetanus, although there were also many examples of those who had superficial wounds. Burns in particular, with or without additional injuries, led to tetanus, although somewhat later. In a group of 37 patients with severe burns, ten developed tetanus ten days, or longer, after injury. The course of the disease in these patients was apparently just as fulminating as in those who developed the disease with a shorter incubation period, and all ten died.

Penicillin was used in six patients with tetanus. Daily amounts of 200,000 units were given to five of these in 25,000-unit doses intramuscularly every three hours. There was no apparent effect upon the tetanus infection. The period of treatment was as follows: two patients received penicillin for six days; one, for five days; one, for two days, and another for 36 hours. All ended in death. One child received a total of 1,200,000 units over a period of 48 hours, the initial dose being 25,000 units given intravenously and 50,000 units intramuscularly — this was repeated every three hours. Again the terminal course was unaltered. Penicillin was used locally in two patients who developed tetanus following burns. The wounds were grossly infected, and penicillin was applied in strengths of 500 units per cc. without evident improvement.

In the last three weeks of February at the San Lazaro Hospital, 140 patients in the group of 156 with tetanus died, a mortality rate of almost 90 per cent. That death was due to tetanus alone cannot be said because of coexisting conditions and other infections. There was little tetanus antitoxin for specific treatment. The facilities for general supportive treatment were also limited and sometimes even the most simple patient care was lacking. Many patients died within a few hours after the appearance of the symptoms of tetanus but many more lived for 3–10 days.

The single most important item available was morphine. This drug in

.008-gram doses reduced the duration and the severity of the spasms. It gave the patient rest and enabled those with dysphagia to swallow liquids that could not have otherwise been administered. Morphine given as indicated, sometimes as often as every two hours, did repress respirations but it was the most useful of the drugs available and I doubt if pulmonary complications were increased by its use. Atropine, .0005 gram, given with morphine definitely improved respiration in severe spasms with marked opisthotonos.

Paraldehyde and chloral hydrate by rectum were well tolerated and effectual to a limited degree. The various barbiturates available were of minimal value. Severe and devastating generalized seizures were sometimes controlled by using chloroform and/or ether as a general anesthesia for short periods in order to give the patient some respite. Rectally, ether in oil, likewise, reduced convulsive seizures and was perhaps the best drug for the purpose under the prevailing conditions. Very little avertin was available but in the few patients who were fortunate enough to receive it the relief was gratifying. The Filipino physicians were unanimous in advocating the use of a 25 per cent solution of magnesium sulfate, injecting it intramuscularly in 2 cc. doses, and employed it almost routinely. It depresses respiration to an alarming degree. Sedatives of all kinds were of some value in controlling seizures and spasms, and by conserving the patient's strength life was frequently prolonged.

During February, March, and April of 1945, almost 500 patients were reported to have had tetanus in various civilian hospitals in Manila. Table I was prepared from information available from the hospitals:

TABLE I

| Hospital | Cases | Deaths | Recoveries |
|---|---|---|---|
| San Lazaro | 200 | 190 | 10 |
| PCAU No. 20 | 150 plus | 137 | Few |
| Emergency | 76 | 40 | 36 |
| PCAU No. 5 | 22 | 6 | 16 |
| Chinese General | 16 | 10 | 6 |
| Philippine General | 6 | 3 | 3 |
| Bilibud Prison | 3 | 3 | 0 |
| | 473 plus | 389 | 71 plus |

It was estimated that there were, during this period, approximately 12,000 civilians wounded, and an incidence of almost 40 per thousand developed tetanus. The mortality rate for the 473 reported cases was 82.1 per cent. These patients for the most part had little or no primary or early surgical care. As far as is known, none had had tetanus toxoid before being injured.

According to the Filipino doctors during the decade prior to the war, there were about 75–100 cases of tetanus in Manila each year. The mortality ranged from 25–35 per cent. Many of the patients were brought to the hospital in the late phase of the disease. The specific treatment during this period was usually 40,000 units of antitoxin per day. Several Filipino doctors of considerable experience expressed the opinion that patients treated

soon after the development of the early manifestations of tetanus with antitoxin had a favorable prognosis.

In 1942, the first year of the Japanese occupation, there was only a slight increase in the total number of tetanus patients. There was little change in the status of the civilian population and there were very few war casualties. Hospital facilities had remained about the same and there was an adequate supply of tetanus antitoxin; thus, the mortality remained at the same level. However, in 1943 the mortality rose to 45–50 per cent. This increase was attributed to the diminishing supply of American antitoxin and the use of serum produced by local manufacture. The local antitoxin was not satisfactory because it was the first attempt to produce tetanus antitoxin in any quantity on Luzon. In the latter part of 1943 the horses being used for this purpose were taken over by the Japanese. Thus, by 1944 tetanus antitoxin had become very difficult to obtain and few patients received it.

During the last quarter of 1944, with the beginning of American bombings of Manila and the resulting casualties, the number of patients with tetanus increased. The mortality rate for the year was estimated as being over 60 per cent, and since there was no tetanus antitoxin available for civilians during the last 5–6 months of 1944, this is probably a conservative figure. In January of 1945 there was a further increase in casualties and medical supplies of all kinds were rapidly becoming exhausted. Sedatives in particular were scarce or unobtainable. The estimated mortality rate was raised to 80–90 per cent.

The incidence of tetanus in Manila under peace-time conditions would indicate that it would be high in combat. The American soldier was fighting under conditions quite similar as to climate and soil. His physical condition was, of course, superior to that of the average citizen of Manila. Furthermore, when wounded he received early and adequate surgical care and, in addition, he had been immunized with tetanus toxoid. That this immunization was completely successful is borne out by the complete absence of tetanus among the U. S. Army Forces on Luzon.

The record of the U. S. Army so far as tetanus is concerned in World War II approaches perfection. From December 7, 1941, to September 2, 1945, a total of 11 cases of tetanus was reported to the Office of the Surgeon General. Over a five-year period, from 1939 to 1943, there was a total of 3,105 deaths recorded as due to tetanus in the United States (Table II).

TABLE II

TETANUS

DEATHS IN THE UNITED STATES OVER A FIVE-YEAR PERIOD

| | |
|---|---|
| 1939 | 637 |
| 1940 | 560 |
| 1941 | 602 |
| 1942 | 698 |
| 1943 | 608 |
| Total | 3,105 |

In the U. S. Army for a five-year period that includes the War, 1941 to 1945 inclusive, there were 14 cases and four deaths. In 1941 there were three cases of tetanus reported, all prior to December 7 (Table III).

TABLE III

TETANUS

CASES IN THE U. S. ARMY OVER A FIVE-YEAR PERIOD

| | |
|---|---|
| 1941 | 3 |
| 1942 | 3 |
| 1943 | 5 |
| 1944 | 3 |
| 1945 | 0 |
| Total | 14 |

Table IV summarizes the patients with tetanus who were reported between December 7, 1941, and September 2, 1945.

TABLE IV

TETANUS

U. S. ARMY—WORLD WAR II

| | Total Cases | Deaths |
|---|---|---|
| No active immunization | 6 | 2 |
| Basic immunization (3 injections) | | |
| No booster injection after injury | 2 | 2 |
| Basic immunization and booster injection after injury | 3 | 0 |
| Total | 11 | 4 |

The length of service prior to injury of the six unimmunized cases occurring after Pearl Harbor was as follows:

| | |
|---|---|
| Injury prior to entry on active duty | 4 |
| Four months of service | 1 |
| One year of service | 1 |

The individual with four months of service was admitted to the hospital four days after induction for surgical treatment of a foot deformity and a cellulitis attributed to wearing GI shoes. He was hospitalized, received no routine immunization, and was subjected to two operations — the first, after the cellulitis had subsided, to correct the foot deformity; the second, for osteomyelitis which followed the first operation. Two weeks after the second operation mild tetanus occurred, from which he recovered. The individual with one year of service was inducted in January, 1941, and injured in February, 1942. Neither the immunization register nor the identification tag were available, but it appeared upon questioning the patient that he had had one dose of tetanus toxoid in November, 1941.

In two cases no booster injection was given immediately following the injury, although the patient had received his basic immunization. One of these patients was injured in North Africa and was first treated in a French hospital and later transferred to an American Evacuation Hospital.

The other case received his injury while on a furlough and was treated by a civilian physician. He received no toxoid until after the onset of the symptoms of tetanus which developed within 48 hours after the injury, and whereas this might be considered by some as a prophylactic booster injection, it was given because of the clinical manifestations of tetanus.

The routine administration of toxoid for stimulating purposes was given to three patients in the series. One of these had had three such injections at yearly intervals; the other two had one. (See Bayne-Jones, *etc.*) In the other two basically immunized patients, less than one year had elapsed since completion of their original series at the time of injury.

There were eight patients who did not receive stimulating doses of toxoid after their injury, and of these, six had received no active immunization. Two patients received tetanus antitoxin prophylactically. In several cases the nature of the injury was not such as would be regarded as requiring protection against tetanus according to the criteria so carefully defined in the Army Medical Corps regulations.

Of the 11 cases of tetanus that developed in the U. S. Army during World War II, only one occurred in a soldier wounded by enemy action, and this patient recovered. Only three soldiers who were fully immunized as prescribed by Army regulations developed the disease. There were four deaths. Two of these occurred in unimmunized personnel. There were no deaths in personnel fully immunized.

Table V indicates the nature of all injuries in this group.

TABLE V

TETANUS

U. S. ARMY—WORLD WAR II

*Nature of Injuries*

| | |
|---|---|
| Gunshot wounds | 5 |
| Burns | 1 |
| 2nd operation for osteomyelitis | 1 |
| Compound fractures | 1 |
| Miscellaneous injuries | 3 |
| Total | 11 |

The method[6] of immunization against tetanus in the U. S. Army has been provided for as follows:

Three (3) subcutaneous injections of tetanus toxoid are administered at intervals of 3–4 weeks. This produces an active immunization that can be reinforced or stimulated by 1 cc. of tetanus toxoid at intervals of one year thereafter. The following alone are indications for subsequent stimulating injections of tetanus toxoid:

(a) Individuals who incur wounds or severe burns on the battlefield;

(b) Patients undergoing secondary operations or manipulations of old wounds;

(c) Others who incur puncture wounds, lacerations, severe burns or other conditions that might be complicated by the introduction of *Clostridium tetani* into the tissues.

The administration of tetanus antitoxin has been limited to the following:

(a) To patients presenting clinical evidence of tetanus:

(b) To individuals who incur wounds or other conditions which necessitate protection against tetanus but who have not previously completed the initial immunization with tetanus toxoid. At least 1,500 units of tetanus antitoxin should be used for passive immunization and at the same time active immunization initiated or completed with tetanus toxoid. Allergic reactions must be kept in mind when tetanus antitoxin is administered because it contains horse serum.

The success of preventing tetanus with toxoid in World War II is ample justification for proposing that all children be immunized against tetanus just as they are against diphtheria. If all school children were so immunized, we might well expect to reduce the incidence of the disease to a negligible figure. With tetanus toxoid immunization the use of antitetanic serum would be unnecessary. A booster shot of tetanus toxoid may be administered at intervals of two years, according to Bigler and Werner,[7] and of course in the presence of wounds indicating it. Anaphylaxis associated with the administration of serum had inhibited the production of a passive immunization, and justifiably so. So far as I know, no instances of fatal reaction in adults or children due to tetanus toxoid have been reported. This is in contrast to the experience with antitetanic serum which has been associated with occasional death.

## CONCLUSIONS

The protection of the American soldier against tetanus by active immunization with tetanus toxoid during World War II is one of the most successful projects yet demonstrated in the field of preventive medicine. The high incidence of the disease amongst the civilian casualties in the battle for Manila (1945) is evidence that danger exists for the unimmunized. Present-day mortality rates indicate that the disease is best controlled by prevention rather than any known therapy of a curative nature. Immunization of all school children with tetanus toxoid should result in a decrease in the number of deaths that occur each year from the disease.

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DISCUSSION.—DR. EDWARD D. CHURCHILL, Boston, Mass.: We have taken for granted this remarkable record of the Army in the prevention of tetanus in World War II, but from the facts Doctor Glenn has put before us, it stands as one of the notable achievements of surgery in this century. It can in no way be underestimated. This is brought home very forcibly when we compare the state of affairs among the German wounded. When the Emory University Unit took over a prisoner of war hospital near Marseilles they found seven cases of tetanus, many of whom died. I asked some of the German consultants why the Wehrmacht had not used tetanus toxoid, and he replied that the medical corps did not always have the support of the high command. They did, I believe, immunize the personnel of the Luftwaffe and some other specialized troops. The Italians did use it.

Certainly Doctor Glenn has called our attention to one of the notable achievements in preventive surgery in this war.

DR. WARFIELD M. FIROR, Baltimore, Md.: There are some papers so clear, so concise, so complete, that discussion is superfluous. Doctor Glenn's paper falls in that category. It serves to emphasize three basic facts about tetanus: First, it is a wholly preventable disease; second, when once well-developed, no form of therapy avails to prevent death; and, finally, it shows that the basic mechanism that brings about death is still unknown.

DR. FRANK GLENN, New York City (closing): I should like to thank Doctor Churchill and Doctor Firor for their discussion and to add one statement—that in my clinical experience I have never seen such a terrifying disease as tetanus.

# SURGICAL TREATMENT OF ANGINA PECTORIS*

## EXPERIENCES WITH LIGATION OF THE GREAT CARDIAC VEIN AND PERICORONARY NEURECTOMY

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IT IS WELL KNOWN that in coronary disease sensory disturbances, vasomotor reactions, and mechanical interferences with the coronary blood flow are always intimately interwoven. It probably never occurs that a single group of these pathologic phenomena acts alone. It is, therefore, fundamentally important to elaborate surgical procedures which would simultaneously block all the nervous deleterious influences and improve the mechanical conditions of the coronary circulation. This basic principle was never lost sight of in the experimental studies that we have carried on since 1935.

To improve the mechanical conditions of the coronary circulation, the value of coronary venous ligation was reinvestigated. To block the action of reflexes, all the important pathways to and from the coronary arteries were resected at the root of the aorta and the origin of the coronary arteries. This last procedure which is obviously more than a sympathectomy, as vagal, sympathetic and sensory branches are resected, is referred to as pericoronary neurectomy.

In 20 dogs, used as a control series, the circumflex artery was ligated at its origin; namely, two to four millimeters from the origin of the left coronary artery. Twenty per cent of the animals survived. In a second group of ten dogs, prepared in advance by coronary venous ligation, the circumflex artery was ligated as in Group I, about one month after. Forty per cent of the dogs survived. It is interesting to note that all the animals which died, except one, succumbed rapidly after the arterial occlusion. In a third group of ten dogs, prepared in advance by pericoronary neurectomy alone, ligation of the circumflex artery was done as in the previous groups at various intervals after operation. Sixty per cent of the animals lived. The interesting point to mention about this series is that not a single animal which died succumbed immediately after the arterial occlusion. In a fourth group of 15 dogs, prepared in advance by pericoronary neurectomy and coronary venous ligation, the circumflex artery was tied again as in the other groups. The survival rate rose to 86.7 per cent. These last results seem to indicate very clearly that coronary venous ligation combined with pericoronary neurectomy decrease substantially the mortality rate after a very high coronary occlusion.

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

Other experiments were carried out with Swenson to evaluate pericoronary neurectomy in abolishing anginal pains. The method originally described by Sutton and Lueth (1930) was used. The results obtained showed that pericoronary neurectomy abolished pain. In our control series of ten dogs, seven gave responses of a high degree which were graded (+++); two gave fairly good positive responses (++); one did not respond (-). In the latter, the negative result was undoubtedly due to the animal's poor condition at the time of the test. Ten dogs operated upon in advance by pericoronary neurectomy gave the following results: Six gave no responses at all (---); one was irresponsive in five tractions on the coronary artery and in one traction the result was questionable because the animal seemed restless (--); two gave doubtful reactions, for they were very active during the rest periods and it is difficult to conclude whether the activity they presented during the tests was due to pain or just to a normal behavior. One only had a positive reaction which was graded (+). It was concluded that pericoronary neurectomy, when technically well done, can abolish coronary pain.

Finally, other experiments were done to see if pericoronary neurectomy could prevent ventricular fibrillation appearing after sudden coronary occlusion. For this purpose, the adrenalin test was used. In a control series, two cubic centimeters of a solution of adrenalin 1:1000 was injected into the left auricular appendage of the intact dog's heart. A sharp elevation in the blood pressure immediately followed, accompanied by ventricular tachycardia and arrhythmia. No ventricular fibrillation occurred. Gradually, the blood pressure and cardiac rate returned to normal. In another series, either the ramus descendens or the circumflex branch of the left coronary artery was ligated at a level that was known by many previous experiments as not high enough to determine ventricular fibrillation within at least one hour after occlusion. One or two minutes after ligation, the same dose of adrenalin as used in the previous group was administered into the left auricular appendage. In all cases, ventricular fibrillation developed within one or two minutes. In a final series, prepared in advance by pericoronary neurectomy, the same procedure as in the latter group was carried out. It was immediately followed by a sharp elevation in the blood pressure, ventricular tachycardia and arrhythmia. In no instance did ventricular fibrillation develop. It seems, therefore, that pericoronary neurectomy helps substantially to prevent fibrillation following coronary occlusion.

The physiologic basis of coronary venous ligation and periocoronary neurectomy as well as the reasons for their association have been discussed at length in other papers. Needless to say, the experiments reported briefly today illustrate clearly that it is fundamental to act simultaneously against both mechanical and vasomotor disorders in coronary disease to achieve better results through operation. Finally, they suggest that coronary venous ligation combined with pericoronary neurectomy should be tried and carefully studied in correctly selected cases of coronary disease.

Sixteen cases have been operated upon during the past six years. They are divided in three groups: In the first, only coronary venous ligation was done. At that period, the experimental work on the coronary nerves was not advanced enough to allow denervation in patients. This group has, however, the advantage of showing the value and limitations of the procedure when used alone. The second group consists of cases of coronary venous ligation combined with pericoronary neurectomy. In the third group —only one case—pericoronary neurectomy alone was performed.

All these patients had a history of coronary thrombosis confirmed by electrocardiographic tracings. Some of them gave a history of two or three attacks of coronary thrombosis. All were practically disabled by "angina of effort" and did not respond to rest and medication. Three died either during or rapidly after operation. In the first group, the cause was pneumothorax tension; in the second, intoxication by quinidine; and in the third, rapid cardiac failure, both coronary arteries being totally occluded at the aortic orifice.

Two of these cases have succumbed since operation. One, a 65-year-old patient with angina and cardiac failure, was discharged from the hospital relieved of his pain. He died three months later from progressive cardiac failure. The other lived during 2.5 years after operation. Before coronary venous ligation, he was not able to walk a block without dyspnea. The slightest emotional upset provoked marked pain. Five months after operation, he walked five miles without resting and had no discomfort. He resumed his work as a janitor. Up to the time of his death, he was examined frequently, and the marked improvement in his condition noticed after ligation was maintained. He died suddenly. His heart was examined and histologic sections showed a high degree of vascularity of the cardiac muscle. Vessels of the posterior and anterior papillary muscles were markedly dilated and gave the appearance of being cavernous. Actual pools of blood were also found in the sections.

Eleven patients are still living; one, six years after the operation. At the age of 65 he is working; his only complaint is a slight dyspnea after exertion. He is now obese and hypertensive. Three patients were operated upon approximately five years ago; they all do the same type of work in which they were engaged before coronary disease incapacitated them, and they have no anginal pain. In the recent group of three patients in which coronary venous ligation was combined with pericoronary neurectomy, one patient is working steadily and has been for 1.5 years; he does not complain of angina. The second case is much improved but states that at the end of the day he often feels pain in his chest of less intensity than before the operation. The third case, operated upon last November, is remarkably well. Before November he was unable to work on account of angina. Subternal pains occurred with bowel movements, and after marital relations, or walking on the level. Since the operation, this pain has been absent. In January he walked in a snowstorm, face against the wind, and

reached his home without having pain or the slightest discomfort. On another occasion, he walked two miles without resting, and immediately afterwards ate a hearty meal. This was not accompanied or followed by angina. He admits that he never could have done this a year ago.

In one severe case, it was necessary to perform the operation in two stages. In the first stage, the ribs were partially resected; and in the second stage, denervation was done. Coronary venous ligation was omitted because we did not dare to prolong the operation. The blood pressure was at a low level. It is too early to evaluate the results in this patient. Yet it is encouraging to note that, since the operation, he has improved a great deal. Formerly he took about six nitroglycerin pills, but now he does not need this medication.

DISCUSSION.—DR. ELLIOTT C. CUTLER, Boston, Mass.: In this afternoon of brilliant papers, I hope this contribution by Doctor Fauteux will take its place as a valuable contribution. In this Association, the greater number of Fellows work in excellent hospitals, and have every facility for assisting and stimulating their pupils in investigative work. Doctor Fauteux has conceived and planned all his work himself. He came to us five years ago, and has continuously prosecuted experimental work out of his own experience and imagination. He has been helped by us largely through technical assistance, and what credit is forthcoming belongs to him alone.

To those interested in the application of surgery for relief of angina pectoris it is common knowledge that two major surgical plans have been proposed:

(a) The first plan is that originated by Francois Franck, a French physician in the last century, who proposed that the division of the sympathetic nerves in the neck might diminish the anginal pain. This procedure was largely practiced in Europe and completely elaborated upon by Rene Leriche. It has received further modification in this country at the hands of J. C. White, and others.

(b) The second method is that which seeks to bring a new blood supply to the heart devitalized by coronary disease. This school of thought is best represented by C. S. Beck in the United States and O'Shaughnessy in England.

Doctor Fauteux has, for the first time, tried to bring these two schools of thought into a common method, and the paper presented today has, I believe, made clear that both the neurologic elements, as well as the injured myocardium, must be considered in any thoughtful attack upon this problem. Moreover, he has brought the neurologic attack to the heart itself and, thus, avoided any injury to the accelerator or depressor apparatuses. His addition of vein ligation as a means of improving the local blood supply is a method which, though it has not produced benefits in other fields, has, by his experiences, seemed to produce benefits in relation to the myocardium.

Finally, he seems to have made secure his point that ischemia *per se* is not the cause of fibrillation, which is the vital element in this disorder. If this be so, it certainly strengthens his viewpoint that interference with the neurologic apparatus must also be utilized in attacking this condition.

DR. CLAUDE S. BECK, Cleveland, Ohio: I want to congratulate Doctor Fauteux on this work. I believe it is an important contribution and I should like to give him every encouragement to keep on with it. This work is difficult. It is difficult in the laboratory where the experiments are done, and it is difficult in the Clinic where laboratory ideas are applied to patients afflicted with coronary artery disease.

I cannot discuss reflexes in the heart. In our work we purposefully avoided consideration of reflexes. I believe the key to the coronary artery problem is in arterial blood supply and oxygen. The fundamental concept underlying our work can

be demonstrated by a simple experiment. A dog's heart is exposed. An area of the left ventricle is selected for the development of a trigger. This area is about two centimeters in diameter. About five small arteries can be seen entering this area. These arteries are ligated. As they are ligated the area becomes cyanotic. If you ligate three or four of these vessels and close the incision, recovery takes place and the heart functions normally. If you continue with the ligation and ligate the remaining artery something suddenly happens. The coördinated beat is destroyed or is replaced by convulsive twitchings of myocardium. Arterial pressure falls to zero. The respiratory center dies and irreversible death follows. To this anoxemia area of heart muscle I applied the term "trigger." To the phenomenon that converted the coördinated contraction and relaxation of muscle fibers into incoördinated contractions I applied the term "discharge." In the presence of coronary artery disease trigger zones develop, discharge and kill. The relationship to blood supply is obvious. A small amount of arterial blood delivered to the trigger can be effective in preventing discharge. A new set of coronary arteries is not necessary.

Blood supply to the myocardium can be augmented in several ways. One, is by the production of extracoronary anastomoses. These are communications between the coronary arteries and the arteries of tissues grafted upon the heart. The second, is by development of intercoronary communications. This is brought about by production of inflammatory reaction on the surface of the heart. The third method is by coronary vein ligation. We studied this subject,* and concluded that ligation of vein had some beneficial effect, that beneficial result probably was not great enough to make application to patients with coronary artery disease, and we suggested that measurements be made by other experimenters. Doctor Fauteux obtained beneficial results by ligation of coronary vein.

I should like to urge members of this Association, who have experimental laboratories, to study the coronary problem. Experiments, well controlled, will be important in advancing this work. Experiments, poorly controlled, will retard development. This experimental work requires accuracy and precision. The importance of the coronary problem is obvious. Again, I want to congratulate Doctor Fauteux.

DR. JAMES C. WHITE, Boston, Mass.: To me this paper is extremely interesting. Interesting because it suggests that there is a possibility that by interrupting vagus as well as sympathetic fibers you may get a better result, and further that by ligating the coronary vein you may get a better result still. In the sympathectomies I have been doing by the posterior approach through the second rib, every patient who has had removal of the three upper thoracic sympathetic ganglions has had relief from precordial pain and arm radiation, but all have known when they were doing too much in the way of exertion—a sensation, not pain, which told them to take nitroglycerin. I would like to know what warning sign there is after Doctor Fauteux's operation. I would also like to know if Leriche has not already shown that after sympathectomy alone the experimental animal is protected from cardiac fibrillation and the mortality rate from high coronary ligation is reduced.

I cannot give you the present exact figures on our patients at the Massachusetts General Hospital, nine of whom have had upper thoracic ganglionectomy and 75 chemical block of the cardiac nerves. Suffice it to say that everyone who has had evidence of effective denervation has been relieved of his intractable angina pectoris. It has amazed us how men, totally incapacitated, who had angina on any effort or even in bed, would come back, so that many could lead lives of moderate activity, and some have been alive and comfortable years afterward. We will check on this again. I hope Doctor Fauteux will go on with his work in Boston, and that we can compare notes on this group of cases.

* The American Heart Journal, 21, No. 6, pp. 767–779, June, 1941.

DR. MERCIER FAUTEUX, Boston, Mass. (closing): It is difficult to show in a few words whether the mechanism of ventricular fibrillation in coronary occlusion is due to ischemia or other factors. We are certain, in our minds, however, that it is not due to ischemia *per se*. Ischemia of the heart was produced by us in dogs in different ways. In these experiments, cardiac standstill was never caused by ventricular fibrillation. The heart gradually lost its strength and stopped in diastole. In the experiments, mentioned briefly by Doctor Beck, where three or four small ligated vessels produced fibrillation, his results, according to his interpretation, indicate obviously that localized cardia ischemia is the cause of fibrillation. Any ligation of coronary arterial branches disturbs the coronary pressure. We have carried out experiments which show definitely that any localized and abrupt change in the coronary pressure can produce fibrillation, even without concomitant ischemia. Other experiments demonstrate that, after coronary denervation, even in the presence of cardia ischemic conditions, the heart does not fibrillate. So, in our minds, we believe that we are beginning to see more clearly the mechanism of ventricular fibrillation after coronary occlusion, and we believe that, if ischemia is the cause, it is not the only one and probably not the most important one.

To answer Doctor White about the signs that replace anginal pain after pericoronary neurectomy, we found that in these patients a sensation of tightness or slight pressure, probably corresponding to their former pain, develops when they overtax the heart. It has been mentioned in regard to the value of sympathectomy in diminishing the incidence of ventricular fibrillation, that the work of Leriche showed that after sympathectomy the mortality rate was lower following coronary ligation. This has been confirmed by most of those interested in experimenting with coronary ligation. In pericoronary neurectomy, however, not only sympathetic branches are resected, but also vagal and sensory branches. The latter procedure seems to have a greater value in the prevention of ventricular fibrillation after coronary occlusion than does simple sympathectomy.

# MANAGEMENT AND REHABILITATION OF NAVAL BATTLE CASUALTY AMPUTEES*†

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COMMANDER DONALD T. JONES, MEDICAL CORPS
LIEUTENANT COMMANDER WILLIAM L. WHITE, MEDICAL CORPS,
CAPTAIN THEODORE E. ORR, MEDICAL CORPS,
CAPTAIN WALTMAN WALTERS, MEDICAL CORPS,‡
UNITED STATES NAVAL RESERVE,
AND
CAPTAIN THOMAS G. HAYS, MEDICAL CORPS
UNITED STATES NAVY
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THIS REPORT is based on the study of 769 patients who had a total of 829 amputations. Fifty-eight of the patients suffered from partial loss of two limbs, while one patient lost three. It will be noted in Table I that 568 amputations involved the lower extremities and only 261, or approximately one-third, the upper extremities.

Amputations were performed in 757 cases because of trauma. Combat was the cause or circumstance of injury leading to amputation in 489 cases, or 64.6 per cent of the 757 cases (Table II), whereas, accidents while on duty led to amputation in 188 cases, or 24.8 per cent. In only 80 cases, or 10.6 per cent, did the accident occur during liberty or leave.

Five hundred and seventy of the original amputations were performed by the now classical guillotine technic, 45 by "open-flap" method, in which partial or adequate flaps were saved and 214 with primary closure. It was noted that when flaps were left, the wound healed much more rapidly and with no more complications than when no flap was left. In those wounds that were healed at the time of this survey, the average healing time of the usual guillotine stumps was 4.5 months, while those on which the open-flap method was employed were healed in an average of 3.5 months.

It has been our policy to secure healing of the wound following the primary amputation and then wait one month before final revision or re-amputation. An analysis of 77 operations performed upon unhealed stumps, here and elsewhere, revealed that serious postoperative complications developed after 27, or 35.1 per cent. This percentage should be compared with later figures on 379 operations on healed stumps in which postoperative complica-

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

† This article has been released for publication by the Division of Publications of the Bureau of Medicine and Surgery of the United States Navy. The opinions and views set forth in this article are those of the writers and are not to be considered as reflecting the policies of the Navy Department.

‡ Dr. Walters has now returned to the Mayo Clinic as head of a Section on Surgery.

tions followed only 64, or 16.9 per cent. These figures show the rationale of waiting for complete healing. This policy, however, presented the greatest problem encountered on this amputee service, for healing of stumps was often slow and prolonged; thus, the period of hospitalization was extended and participation in the outlined program of rehabilitation was delayed.

TABLE I

AMPUTATIONS

| | Amputations | |
|---|---|---|
| Upper extremity: | | |
| Fingers | 45 | |
| Partial hand | 22 | |
| Forearm | 79 | |
| Arm | 115 | |
| Total | 261 | (31.5 per cent) |
| Lower extremity: | | |
| Toes | 24 | |
| Partial foot | 44 | |
| Below knee | 230 | |
| Thigh | 270 | |
| Total | 568 | (68.5 per cent) |
| Grand total | 829 | |

Numerous methods were used to promote healing. These included whirlpool baths, applications of infra-red and ultraviolet light, various antiseptics and antibiotics, skin traction and skin grafts. Whirlpool baths seemed to stimulate healing in those cases in which peripheral circulation was adequate and the region to be epithelized was small or of moderate size. Split-skin grafts were of value even when they appeared to be failures because they apparently stimulated vascularization of the granulating tissue.

Cultures were taken of these wounds (Table III), but the rôle of bacteria

TABLE II

CAUSES OF INJURIES: 757 CASES

| | Cases | Per Cent |
|---|---|---|
| Combat | 489 | 64.6 |
| Accidents on duty | 188 | 24.8 |
| Accidents on leave or liberty | 80 | 10.6 |

TABLE III

TYPES OF BACTERIA FOUND IN WOUNDS LISTED IN ORDER OF FREQUENCY

1. *Staphylococcus aureus*
2. *Pseudomonas aeruginosa* (*Bacillus pyocyaneus*)
3. *Escherichia coli*
4. *Bacillus subtilis*
5. *Proteus vulgaris*
6. *Nonhemolytic streptococci*
7. *Hemolytic streptococci*
8. *Streptococcus faecalis* and rarely *Clostridium* and *Gaffkya tetragena* (*Micrococcus tetragenus*)

in inhibiting healing could not be determined. The bacteria found were typical of those usually found in chronic wounds, and they probably represent a reflection of the type of nutrient available rather than a tissue infection.

Simple dry dressings of fine-mesh gauze were used as the fundamental or basic dressings. For approximately one-third of the stumps, these appeared to be the dressing of choice, although healing was seldom rapid. Various types of local treatment were used to promote healing. These included most of the acceptable ointments and solutions. The effect of topical medication on the rate of healing of open stumps has varied so widely that it is impossible to say that any one agent has been particularly effective (Table IV).

TABLE IV

EFFECT OF CERTAIN LOCAL AGENTS ON HEALING OF OPEN STUMPS

| Agent | Stumps Treated | Results | | | | |
|---|---|---|---|---|---|---|
| | | Made Worse | No Change | Slightly Improved | Improved | Per Cent Improved |
| Hypertonic solution of sodium chloride | 7 | 0 | 4 | 1 | 2 | 28.6 |
| Solution of chlorophyll | 10 | 2 | 3 | 3 | 2 | 20.0 |
| Azochloramide | 52 | 0 | 32 | 11 | 9 | 17.3 |
| Streptomycin | 37 | 0 | 20 | 10 | 7 | 18.9 |
| Penicillin | 19 | 0 | 9 | 7 | 3 | 15.8 |
| Zinc peroxide | 71 | 2 | 28 | 24 | 17 | 23.9 |
| Castellani's paint and elastoplast | 19 | 4 | 2 | 2 | 11 | 57.9 |
| Daily whirlpool bath | 32 | 5 | 13 | 5 | 9 | 28.1 |
| Total | 247 | 13 | 111 | 63 | 60 | 24.3 |

Therefore, these agents were employed primarily in preparing the stump for skin grafting. The most useful agents for this purpose were 2 to 5 per cent solutions of sodium chloride, zinc peroxide and streptomycin. The hypertonic solutions of sodium chloride and zinc peroxide were found to be valuable in removing slough and purulent exudate, as well as in reducing edema. Streptomycin was used topically to eliminate the gram-negative bacilli, particularly *Pseudomonas aeruginosa* (*Bacillus pyocyaneus*). Although it effectively accomplished this purpose, it did little toward influencing healing or actually increasing the percentage of takes of the skin grafts. Daily whirlpool baths were useful in cleansing the lesions prior to grafting.

When the wound had not healed after several months and there was extensive fibrosis of the stump the application of Castellani's paint, followed by an elastoplast wrapping which encased the entire stump, promoted healing in 11 out of 19 cases. These dressings were left in place for five to ten days and were used in the same manner as Unna's paste boots for varicose ulcers.

It was apparent that the wounds in which adequate skin traction was employed from the time of operation healed much more rapidly than those in which this procedure was neglected or contraindicated. Anteroposterior application of moleskin tape, with or without a spreader, moleskin tape on four sides, with a spreader, and stockinette traction with which Unna's paste,

rubber cement or special adhesive compound is applied were used as indicated and alternated to suit conditions. In spite of the various procedures and materials used, in some cases it was impossible to maintain adequate traction on the skin because of perspiration, local irritation of the skin, associated injuries or lack of coöperation of the patient.

### REVISION AND REAMPUTATION

After healing of the open stump had occurred, plastic repair or revision was usually a simple operative procedure. It consisted of excision of the terminal scar, preferably with a horizontal elliptical excision, and of undermining the proximal skin and subcutaneous tissue as indicated. The bone and its adherent fascia was not molested unless reamputation was contemplated. When closure was made under any degree of tension, skin traction was applied. If painful neuromas were present, these were removed at the time of revision by isolating the nerve, placing moderate traction downward on it and transecting it with a sharp razor blade at a higher level. Nerves were not routinely injected or ligated.

In these plastic revisions it is not possible to keep to the principles of good surgery, because closure was always accomplished under some degree of tension, over an ischemic region in which complete hemostasis was almost impossible to obtain.

The levels of amputation of choice are given in Figures 1 and 2.

Disarticulations through the wrist, intercarpal or carpometacarpal joints were done in five cases, and a prosthesis which utilized the pronation-supination function of the wrist has been constructed for use in these cases. By this means the cross-shoulder halter was eliminated and more direct control of the movement of the prosthesis was achieved. It was found that the styloid processes of both the radius and the ulna must be intact before use of this type of prosthesis was feasible. When the short stumps of the forearm were of inadequate length for a prosthesis, additional length could be gained by grafting skin and bones or by transferring the biceps tendon to the brachialis insertion. Lengthening of the humeral stump was done in a few selected cases in which it was indicated. The head of the humerus was retained for better cosmetic appearance and easier fitting of a prosthesis.

For the lower extremity, we have preferred the Syme amputation for amputations about the ankle, while in two cases the Boyd type of arthrodesis has been performed. After amputation about the knee, two patients have been fitted with a bent knee type of prosthesis, but the majority of our conversions were to a Gritti-Stokes type. The head of the femur was retained if possible, to give a wider base to rest on a tilting table type of prosthesis.

### ASSOCIATED CONDITIONS

Associated injuries were common in these patients. Of the 757 patients who had amputations because of traumatic injury, 406 or 53.6 per cent had associated injuries. There were 149 cases of fracture, of which 90 were cases

of compound fracture and 59 of simple fracture. Extensive loss of tissue, bone, muscle and skin was associated with the compound fractures sustained in combat. In 23 cases, or 25.5 per cent of the cases of compound fractures, osteomyelitis developed.

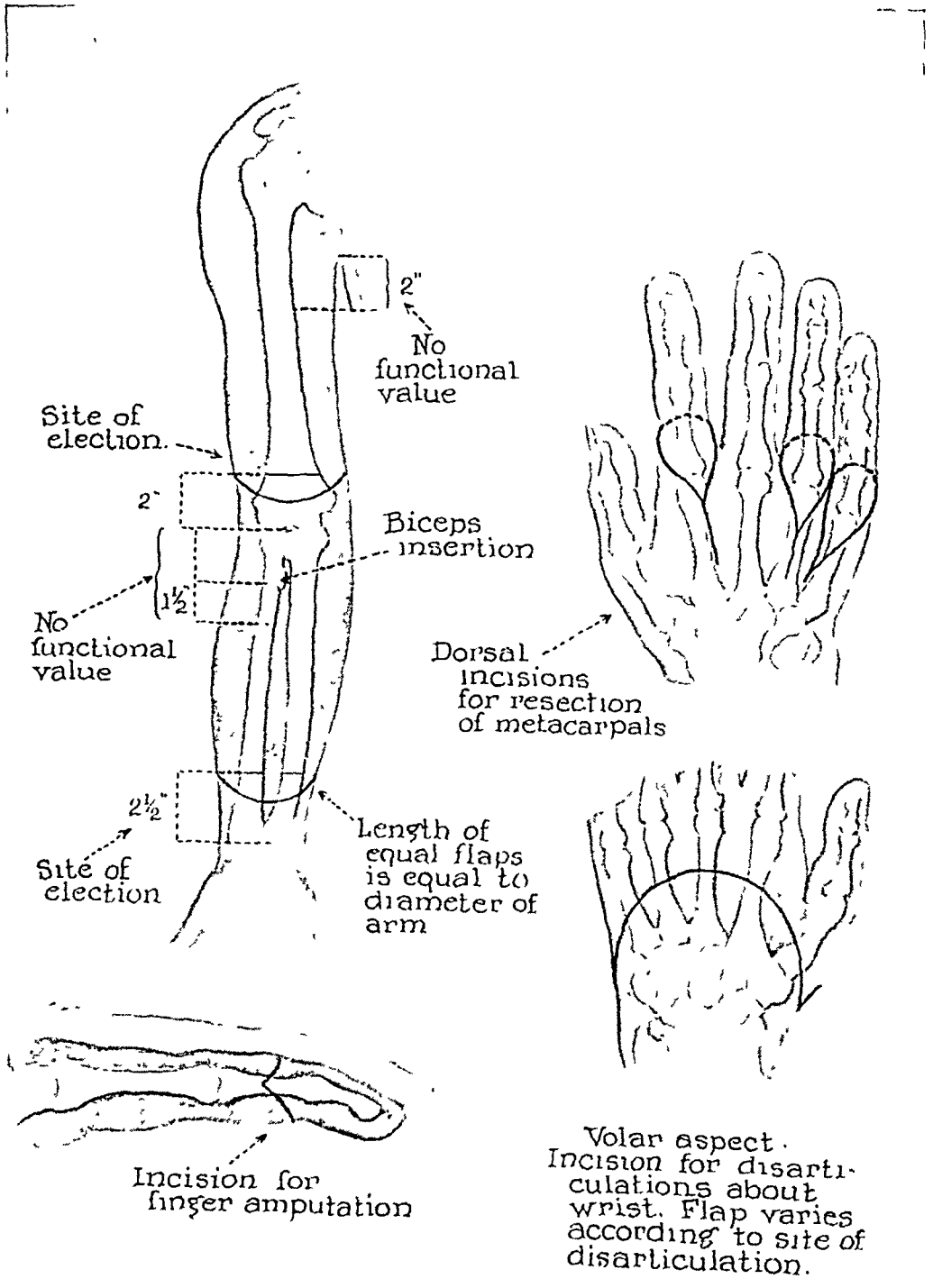



FIG. 1.—Amputation levels and skin incisions on upper extremity.

Contracture of the joint proximal to the site of amputation was found in 84 cases. This was due to scar tissue, muscle imbalance, painful stump and, finally, contracture of tissue about the joint. Physiotherapy and supervised muscle exercise, such as weight lifting, improved the condition in the ma-

jority of cases. Wedge casts, traction and manipulation under anesthesia improved the contracture in most of the remaining cases. Tenotomies were required in only a few cases.

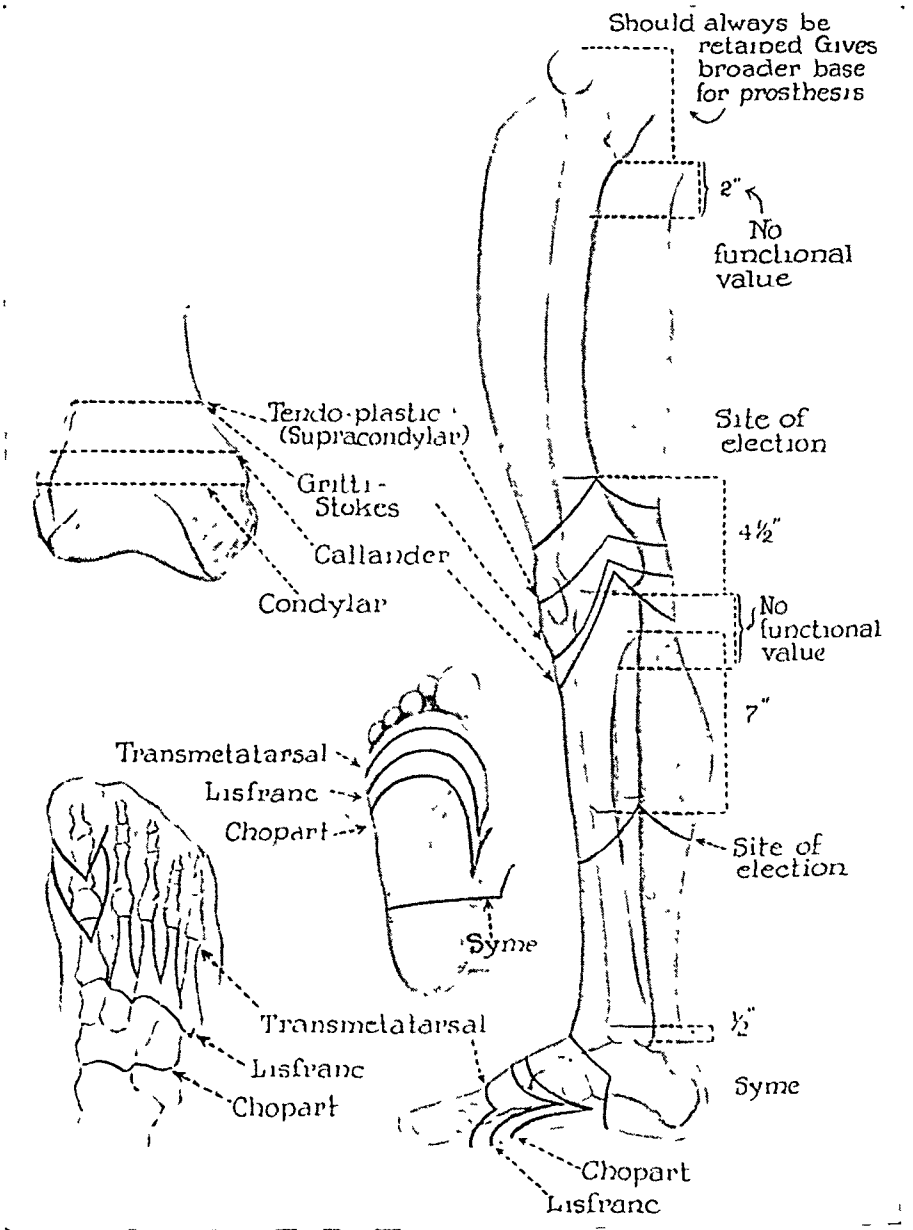



FIG. 2.—Amputation levels and skin incisions on lower extremity.

Extensive damage to the proximal joint due to penetrating wounds with infection and subsequent destruction of the articular surface occurred in 14 cases. Treatment consisted of immobilization of the joint in the position of maximal function, adequate doses of penicillin and sequestrectomy when indicated.

Twenty-five patients had associated nerve injuries. In the cases in which

wrist and foot drop occurred braces were employed and physiotherapy was carried out before and after exploration by the neurosurgeon.

### PROSTHESES AND REHABILITATION

We have been fortunate in having an artificial limb shop in our department, under the supervision of Lt. Basil Peters, who had had 20 years of experience in the making of artificial limbs. The limb shop was staffed by Service personnel who had had no previous experience in making artificial limbs, but who had aptitudes in allied fields, such as leather-working, wood-working, *etc.* A laminated plastic was used as the basic material. This was formed by wrapping cotton duck canvas around the limb mold and impregnating it with a plastic resin glue. The plastic material may vary in thickness from three- to five-ply, or from $\frac{3}{32}$ to $\frac{1}{8}$ of an inch (0.24 to 0.32 cm.). A total of 513 prostheses were constructed in the 18-month period covered in this report.

Classes in driving automobiles were instituted in November, 1944, and have been of great value. The course consisted of several lectures on the elements of highway safety, instruction in a laboratory car on rollers, and practice with the Aetna reactometer to lessen the time for braking. Advanced instruction was given in the streets of Philadelphia and the final examination was given by the Pennsylvania State Police.

Follow-up data were available in 200 cases (Table V). Approximately

TABLE V

FOLLOW-UP DATA ON REHABILITATION IN 200 CASES

| | Per Cent |
|---|---|
| Back to old job | 20 |
| New job | 38 |
| School or college | 20 |
| No activity yet | 22 |

78 per cent of these patients were either working or continuing education. A permanent lack of adjustment is not necessarily indicated for the group who reported no activity, as some of these patients had been discharged only recently. Some were taking a "well-earned rest," as they said; others are availing themselves of unemployment insurance.

### CONCLUSIONS

1. Open-flap method of amputation is recommended for amputations performed as emergency measures.

2. The early and constant use of skin traction cannot be too strongly stressed.

3. Various local agents are of value in eliminating certain types of bacteria from granulating wounds in preparation for skin grafting, but have not been found to hasten healing.

4. Revisions and reamputations through healed wounds are recommended whenever possible.

5. Disarticulations through the wrist, intercarpal or carpometacarpal joints are offered as satisfactory amputation levels.

6. With an adequate rehabilitation program, a large number of amputees are returned to a satisfactory and productive civilian life.

DISCUSSION.—LT. WILLIAM L. WHITE, Philadelphia, Pa.: My particular chore in this program has been concerned with healing of these open stumps before the final revision or reamputation. At six to ten weeks, or more, following guillotine amputation, when these patients were admitted to Philadelphia Naval Hospital, the stumps usually presented a uniform appearance, with the bone ends being covered by a pad of fibrous tissue of varying thickness, on the surface of which there was usually pale, dirty granulation tissue. These lesions are not unlike other indolent ulcers in which healing is retarded by inadequate blood supply. The most serious healing problems were encountered in below knee and partial foot amputations. We have endeavored to preserve all functional joints and bone length even at the expense of extended hospitalization, which is sometimes costly in view of the patient's mental adjustments.

The measures we have employed to secure healing may be divided into five classes as follows: First, the routine use of skin traction; second, local therapy designed to eliminate bacteria or improve the state of the wound; third, the use of the Thiersch grafts or pinch grafts; fourth, open revision of the wound with partial or secondary closure; fifth, the use of pedicle grafts, the value of which has not yet been determined, since none has been given an adequate test of time. Probably the best method in healing stumps has been the use of free split-thickness grafts.

MAJOR GENERAL NORMAN T. KIRK, Washington, D. C.: I want to congratulate the essayists. The paper presented is an excellent analysis of quite a group of amputees. Our experience in the Army more or less corresponds with the report made. Our job, of course, was quite a bit larger.

Five amputation Centers were initially set up by the Army. This number proved to be insufficient and was increased to seven. Initially, it was intended that only 750 patients be treated in any one Center; actually, there have been more than 3,000 amputees admitted to Percy Jones General Hospital since its opening.

I cannot agree with the statement that the flap-type guillotine amputation is superior to the circular type. Our experience in this war and the opinion expressed by our civilian consultants was to the effect that the circular type guillotine was the operation of choice in battle casualties where extremities had to be removed following trauma or to control infection. The circular type guillotine is not a "chop" operation. If it is properly performed there is ample soft tissue for closure without bone shortening. In the amputation by the open-flap method, traction is applied with difficulty; yet it is essential. Flaps frequently shrink and deform and do not present nearly so nice a stump after healing as does the circular type.

Skin traction, using adhesive plaster or skin glue with stockinette, is a part of the after-treatment of the open reduction and is as essential as a Levine or Miller Abbott tube for the treatment and control of ileum or intestinal obstruction. It is at times applied with difficulty and its maintenance is sometimes difficult, but not impossible if there is a will to carry it out.

Our experience has shown that a disarticulation at the wrist can be well fitted with a prosthesis and pronation and supination retained. Northrop has developed an excellent forearm prosthesis which permits pronation and supination of the appliance with amputation as high as the juncture of the upper and middle thirds of the forearm.

We feel that the skin grafting of the unhealed stump end prevents what we desire to accomplish by skin traction, and if the latter is properly applied the former will not be necessary. An unhealed area in the stump end is not *per se* a contraindication to

plastic revision. If the wound looks clean and healthy and the stump end is free from edema, closure is just as safe from an infection standpoint as if the stump end has been previously skin-grafted.

Fortunately, with the use of sulfa drugs and penicillin, the infection rate following the plastic closure of stumps is much less than in World War I. I am unable to state at the moment the exact instance of infection and other complications such as hematoma or necrosis. Fascia closure in the repair of the circular type guillotine stump is not essential, as it is in the primary one-step closed operation. Skin grafts will not stand up when the prosthesis is worn. Pedicle grafts may be used, but before the prosthesis is applied innervation of the graft must have become effected or atrophic changes will occur.

CAPTAIN T. G. HAYS, Philadelphia, Pa.: I would like to say a word about rehabilitation in connection with amputees. The amputee gives an excellent opportunity to do rehabilitation work that will enable him to go out to a useful occupation. When he enters the hospital, he is given a physical examination, the stump is examined, roentgenograms are ordered, and then he is interviewed by the educational service officer. He is asked what education he has had, what he would like to do in the future, how much schooling he desires. Well-qualified instructors are available from the best institutions; courses can be obtained; any textbooks desired can be had, and the amputee can start training for his future in life while still under treatment, which I think is very important. Study keeps these patients occupied, and we know a person who is busy is not a trouble maker. Typing is taught, with typewriters adapted to the use of the individual. Physical training is started at that time and each is given a work-training project. They start training for the work they intend to carry on and are able to obtain part time paying jobs; during the war that was worth much to the men themselves and also aided in the war effort.

After the man is measured for his prosthesis, he is put in the group exercise class with amputees of the same type. The prosthesis is not delivered to the patient, but to the walking class, and he wears it under supervision. At the end of the walking class the stump is examined to see if there is skin irritation and any necessary adjustments are made. When he has completed his walking class he is given 30 days leave. He wears his prosthesis home and when he returns, if everything is satisfactory, he is given his discharge. He is then able to take his place in life.

DR. WALTMAN WALTERS, Rochester, Minn.: It was an interesting experience for me to have an opportunity to see and follow the Naval Marine personnel whose battle casualties had necessitated amputations, from the time a few days after the amputations were performed aboard a hospital ship or at one of the advance fleet hospitals, later at intermediate points on their way back to the United States and finally at the U. S. Naval Hospital, Philadelphia.

As has been mentioned, approximately 25 per cent of the amputations were performed because of accidents while on duty. While visiting one of the Fleet Hospitals at Guadalcanal, where one of our members, Doctor Deever, was Chief of Surgery, three patients who sustained crushing blast injuries to their lower extremities from an explosion were brought into the hospital. In two, emergency amputations were performed; on the third, whose condition was too serious to allow use of supportive therapy, an amputation was carried out by refrigerating his extremity.

In the forward areas the amputations had been done by younger surgeons whose Naval medical training had emphasized the safety and value of the guillotine type of emergency amputation necessitated because of battle casualties. I am sure that this accounts for the fact that a relatively small percentage of the patients had open flap types of amputations. Moreover, in Naval warfare, and with the type of evacuation which was necessary, in many instances it was difficult to use any method of applying traction to the skin of the open guillotined stump.

In Philadelphia, the coördinated program of the treatment and rehabilitation of the amputees had been established by Captain C. M. Shaar and was functioning in excellent fashion upon my arrival. The coördinated program has been outlined to you in the abstract of the paper which Doctor Ryan has presented.

In view of the marked reduction in the incidence of infection in cases of reamputation where the stump had been covered either by a plastic revision or skin graft in contrast to patients with open stumps, Doctor White and I were anxious to study the effects of various antiseptic agents upon the bacterial flora of the open stump to see which was the most efficient in promoting more rapid healing of the open stump. The results were described in our paper and need not be repeated.

The correlation of the departments of general, orthopedic and plastic surgery, with the aid of the psychiatrist and the rehabilitation officer, made it possible to employ to the fullest extent in the care of the amputees all the scientific advice available in the treatment of this group of patients. For example, the plastic surgeons assisted us by employing the use of full-thickness pedicle skin grafts to lengthen the soft tissue portion of the ends of some of the short stumps into which bone grafts were later placed to improve the function of the extremity or to permit it to take a properly fitting prosthesis.

The morale of all the amputees was excellent; in fact, they were some of the most cheerful patients in the hospital.

Many of the patients who had had amputations were at the same time victims of additional injuries. These consisted of compound fractures, penetrating wounds of the abdomen and chest, and injuries of the head. Time did not permit a discussion of the treatment of these associated injuries.

The associated service of psychiatry, psychology and rehabilitation were of great assistance in the care of these patients. I am certain that the early fitting of a permanent prosthesis contributed a great deal to the morale. Lessons were given in walking in front of a mirror, dancing and driving an automobile which not only exercised the extremities, but use of the prosthesis could help to restore confidence in being able to walk or to use the arm in a useful fashion. The prostheses were "tailor-made" to order, and were light, durable and efficient. Comments were frequently heard referable to a comparison of the prostheses furnished by the Army and Navy, each extolling the virtue of his own prosthesis, or those of his particular branch of the service, whether Army or Navy.

Lastly, too much credit cannot be given to the group of Naval specialists designated as psychologists, physical therapists, occupational therapists and Red Cross workers who, with doctors and nurses, pooled their knowledge and experience in trying to evaluate those qualities in each boy which would lead him to make an early recovery, adjustment, and return to his former civilian occupation; or to find some other which, by virtue of instruction or training, would fit him to earn a livelihood. An excellent job was done as a result of this correlated care of the amputees.

As the proof of the pudding is in the eating, the follow-up which was carried out in 200 cases of amputees treated at the U. S. Naval Hospital in Philadelphia shows that 78 per cent were either working or continuing their education, and as Doctor Ryan has said—"A permanent lack of adjustment is not necessarily indicated for the group who report no activity, as some of these patients had been discharged only recently and some were taking a well-earned rest."

# THE NEW VIEWPOINT TOWARD SPINAL CORD INJURIES*

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IN NO PREVIOUS WAR, nor in civilian life, has the patient recovering from the immediate effects of a spinal cord injury been considered particularly a problem. In general, it has been taken for granted that he was a hopeless cripple and that, from bladder infection with its sequelae, his life expectancy was brief. Nursing care and narcotics were in most instances the main treatment. The entire attitude has changed in the past few years. We now know that many of these patients can be cleared of infection and live as long as any one else, that bed sores can be closed with good tissue, that locomotion is possible, and that jobs can be found for them. Many minds have been at work once it was recognized that the previous pessimistic attitude was unwarranted. The team work required to obtain these results as it was developed in the Army needs to be more widely understood.

In World War I 80 per cent died within the first few weeks as a result of catheterization and bed sores. Cushing reported 32 patients with spinal cord damage cared for in the forward areas. Eight were inoperable and all of them died. The other 24 were operated upon and 15 died, a mortality of 62.5 per cent. In World War II rapid and efficient evacuation of the wounded, measures to counteract shock, chemotherapy and greater understanding of nutritional management have combined in restoring to physiologic balance many who would have died early.

In the Army there have been about 1,400 patients with paralysis from spinal cord injury who survived long enough to return to this country. These were divided among about 20 Neurosurgical Centers. While they were considered neurosurgical patients, their care was less from this section than from urology, orthopedics, general surgery, medicine, laboratory and neuropsychiatry. The efficiency of care was in proportion to the team work shown and the ambition of the particular ward officer placed in charge. Few have died since arrival in the United States and these were chiefly in the early days.

1. *Care Abroad.*—The first consideration was speedy evacuation from the front, when possible, to a Neurosurgical Center in the rear echelon. An indwelling catheter, not clamped off, was inserted on the way. The prone position in transit was the most satisfactory. At the Neurosurgical Center in a General Hospital excision of the wound with exploration of the spinal cord was usually undertaken. Several weeks' treatment was then required in preventing and treating urinary sepsis and decubitus ulcers and improving the general condition. Of course, a large proportion of these patients had other complications, *e.g.*, compound fractures, chest and abdominal wounds.

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If rapid transport from the front was impossible, neurosurgeons at Field or Evacuation Hospitals instituted similar treatment as well as possible. Hyperextension was contraindicated because of the danger of bony fragments being pressed farther into the spinal canal. In the majority of instances a suprapubic cystotomy was done before patients were sent to the Zone of Interior, as a surer method of preventing distention of the bladder during long transport with possible delay *en route*.

2. *Care of the Urinary Tract.*—This is a major concern. In all serious injuries of the spinal cord this is the immediate problem and persists as long as paralysis does. Tidal drainage is the best emergency and definitive treatment. This keeps the bladder free of serious sepsis, maintains normal bladder capacity, and preserves the tone of the muscles of the bladder wall. After three or four months many are able to obtain voluntary control of bladder function and a large majority of those with permanent paralysis establish automatic bladders without clinical evidence of infection. The frequent interchange of fluid in tidal drainage also cuts down the formation of calculi and accumulation of mucus. Various solutions have been used for this, all with enthusiastic advocates. Of course the bladder arriving with a suprapubic opening must heal before tidal drainage is instituted.

Urinary sepsis is combatted by chemotherapy according to the sensitivity of the predominating organism. This sensitivity is gradually lost to the sulfa drugs and much more rapidly to streptomycin. They should, therefore, be used only as urgently required from the clinical, not urinary culture, standpoint until the suprapubic wound is healed and catheter drainage is no longer required. Streptomycin will rid the bladder urine of proteus bacilli in 12-24 hours, but with wounds or foreign bodies in the bladder their number may be as great four or five days later. Sensitivity to streptomycin diminishes rapidly and its use is of no permanent value when suprapubic drainage or a catheter is present. Pyelonephritis will be common if bladder retention is allowed to persist.

The urine must be kept acid and the pH between 4.5 and 5 as prophylaxis against calculi, both bladder and renal. Irrigations with M solution, if tolerated, seem most efficient in keeping stones soft. Bladder calculi are about two or three times as common as renal calculi, and the two combined occur in 20-30 per cent of patients. Routine abdominal roentgenograms are needed at least monthly. Recurring episodes of fever are frequently based on calculus obstruction. Pain is not felt, so does not give us a clue to the situation. Operation for renal calculi is to be avoided as far as possible, since conditions giving rise to calculi will still be present postoperatively. Bladder stones can usually be removed by crushing and evacuating. The treatment of the bladder *per se* is at no time a bar to ambulation, which is of great assistance in improving all aspects of the urologic problem.

3. *Care of the Bowels.*—Frequent digital examinations to rule out impaction are necessary. Mild laxatives should be given occasionally and a slowly administered retention saline enema is given routinely every three days. Chair

patients are taught to maintain latrine habits. A fixture needs to be installed in the toilet so that the patient can lift himself from wheel chair to toilet without assistance.

4. *Supportive Therapy and Nutrition.*—Patients with protein levels below 6-8 grams per cent or hemoglobin below 80 should have transfusions. Hemoglobin and total protein should then be determined weekly, with repeated transfusions given until a normal level has been reached for two weeks. After this the tests should be made on each patient every four weeks. Food must be high in protein content, at least 180 grams daily, and served in an appetizing manner. Food must also be high in calories and vitamins. In extreme nutritional problems gavage or parenteral feeding is employed, using protein hydrolysates and other protein formulae. Unless positive nitrogen balance is maintained, none of the other problems of the patient will progress favorably, notably wound healing and resistance to infection. Even 300 grams of protein a day may be required. The average weight loss in one group of 82 patients between time of injury and arrival in this country was 50 pounds.

5. *The Decubitus Ulcer.*—Over 75 per cent will show ulcers from the size of a silver dollar to that of a dinner plate. These patients must be turned every two hours day and night if on a hospital bed and more often if on a litter or canvas cot. Stryker frames have proved of great value in allowing ready change of position. The formed ulcer is grossly infected with urinary and bowel tract organisms. Excision of necrotic tissue should be performed daily until no more sloughing tissue is present. The ulcer must be isolated by the dressing from continued contamination from feces and urine. With a good nutritional state established, the ulcer shows progressive spontaneous healing. With the ulcer healed, positive nitrogen balance is often rapidly attained, whereas it was difficult or impossible to maintain previously. The scar of spontaneous healing or a split-thickness graft tends to break down frequently with formation of new ulcers. For these reasons and because the necessary early ambulation is impossible with a large decubitus ulcer, surgical closure has proved most desirable and a tremendous time-saver. Full-thickness flaps of skin and subcutaneous tissue from adjacent surfaces of any required extent are rotated to fill the defect. Atrophy of the glutei muscles usually leaves an abundance of loose skin to be borrowed from the buttocks. Before operation the floor of the ulcer must be covered with healthy granulations and the margins must be fixed with growing epithelium. At operation the ulcer is completely excised including both the peripheral rim of scar tissue and the granulating base. Undermining and shifting is then done to any extent necessary. Nonabsorbable ligatures and sutures are used throughout with a most meticulous closure. The results have been excellent with healing usually within two weeks.

6. *Ambulation.*—The chief desire of the patient is to be able to walk again. Every effort must be made to see that this desire is fulfilled. The entire exercise program is planned with this end in view. Exercises of the upper extremities and shoulder girdles are commenced while confined to bed, are continued

when allowed in a wheel chair and are transferred to a mat as soon as the patient is able. Power of abdominal and back muscles must be increased also. For a life of crutch-walking the unaffected muscles must be especially developed. Before the patient can stand or attempt crutch-walking he must be custom fitted with bilateral lower extremity braces, frequently extending no higher than the upper femoral region. They must be light, but strong enough to give confidence. They must immobilize his knee joints and not allow his feet to drag. They can be made so that a pair of braces with shoes without a pelvic band weighs three pounds for each extremity.

Physical therapy is necessary for the lower extremities from the first. One seldom knows that complete paralysis will persist. Passive exercise of lower extremities is given for reeducation. There may be a flicker in some muscles and continued guided exercise of these may later allow a change from a long caliper to a foot drop brace only. Functional activities, *e.g.*, shaving, putting on socks and slippers, are required from the time a patient is able to sit erect and balance himself.

The patient graduates from mat exercises for upper extremities and trunk to standing exercises in parallel bars and crutch-balancing exercises. Next comes actual training in ambulation with crutches and braces. Two gaits are taught—the "step-through" and the "swing-through." The "step-through" is much harder to learn, but gives the appearance of more normal locomotion. The "swing-through" can be learned readily after the other is mastered and the patient can then use either which seems to fit his needs at the moment best.

Having learned to rise from bed to chair, from chair to standing position, from this to crutches and then to negotiate curbs and steps, the next instruction is in driving an automobile with hand controls. State motor vehicle bureaus are giving licenses to these men after examination. Throughout this whole exercise program a chart is kept showing the time of accomplishment of each of some 60 achievements. The possible morale factor in arousing competitive spirit in this way is evident. Success in ambulation is a great aid to practically every other problem of the paraplegic.

7. *Pain.*—From a third to a half of these patients will have some form of unpleasant sensory disturbance more or less persistent. Narcotics should be denied as much as possible because of habit-forming effects. Pain may be a tingling sensation, moderate or agonizingly severe root pain of segmental distribution, or of a causalgia type usually in one extremity only. Pain tends to decrease spontaneously with time and improvement in general condition and activity. But in a certain number, probably less than ten per cent, pain has been persistent or severe enough to require surgical intervention. Posterior rhizotomy, nerve root section, has been applicable, particularly in cauda equina lesions, and because it preserves all possible nerve function. The sensory roots are often found at operation glued to cord or dura by dense adhesions, partly torn, or adherent to rough spicules or fractured bone. Cordotomy, section of one or both lateral spinothalamic tracts, should generally be reserved for the

most severe cases not relieved by rhizotomy. With evidence of causalgia lumbar sympathectomy is of course the choice.

8. *Spastic Contractions.*—These have first appeared at intervals of from two weeks to seven months after injury. In one series of 41 lesions of the thoracic cord 80 per cent had spasm, and, in general, this condition appears in about 40 per cent of the entire group. Spontaneous improvement occurs in many when they become ambulatory and operation should be done only in those with such severe spasm that ambulation is impractical. If the cord lesion is complete, an attempt should be made to make the patient ambulatory by the simplest possible procedure, *e.g.*, section of the obturator nerve for adductor spasm. If unsuccessful, intrathecal alcohol or anterior rhizotomy should be considered. If the lesion is incomplete there should be delay of at least one year after clinical improvement has ceased before any destructive operation is done.

9. *Psychologic Readjustment.*[1]—A spinal cord injury usually occurs suddenly. With its violent reception there is an instantaneous change in the state of the individual from one of independence to almost complete dependence on others for transportation, nourishment and disposal of body excreta. The adult suddenly returns to the infantile state. Depression, even with thought of suicide, is the common initial reaction. A period of expectation that his legs will move again follows, often fostered by misguided statements of those around him. With his physical dependence he becomes less mature emotionally also, as shown by irritability and fits of anger. He becomes fearful of everything—being a burden, having to leave the hospital, having to earn a living. He deceives himself into thinking that time will result in complete recovery of his lost functions. At some time the extent and permanency of his condition has to be explained to him. Then he must be told the things he can do in the future within the limitations of his handicap. He must also be shown this by having the opportunity for actual training in suitable vocations. His psychologic rehabilitation needs to be carefully handled coincident with his physical rehabilitation.

In trying to accomplish this the services of the American Red Cross, Occupational Therapy, and the educational and shop programs have played a large part. Recreation, particularly of the type in which he takes an active part, training in arts and skills, helping in adjustment to his family, giving the patient an opportunity to explore his potentialities both for an occupation and for hobbies, all play an important part in readjusting the man to his incapacity.

What does the future hold for these men? Their rehabilitation must be continued with the use of great imagination. Otherwise they will be "merely living memorials to the skill of medical officers during World War II, but to no good purpose. They must be given something beside just the privilege of staying alive."[1] The value of this work to us is that in the occasional similar patient we come across in civil life, we shall appreciate the many facets of the problem to be considered and the variety of specialists needed in each instance.

Patients with spinal cord injuries may be helped in a multitude of ways. Preservation of life, at least, is no longer hopeless.

## REFERENCE

1 Thom, Douglas A.: Personal communication.

DISCUSSION.—DR. CONDICT W. CUTLER, JR., New York City: "A defeatist attitude is intolerable in the care of patients with traumatic transverse myelitis."

This opening statement of Technical Medical Bulletin No. 162, issued by the War Department in May, 1945, sets the standard and suggests the program for the treatment and rehabilitation of patients with spinal cord injuries.

There is little one can add to Doctor Kennedy's careful presentation of this program and its results. One can only affirm the effectiveness of the plan and add some further observations on particular phases of the problem.

At the close of hostilities, there were 88 patients with cord injuries under treatment at the Cushing General Hospital. At the time of their reception they were emaciated, anemic, with evidence of profound avitaminosis, incontinent of feces and with suprapubic cystostomies, afflicted with large decubitus ulcers, and in a low state of morale. By means of transfusions, proper alimentation, and vitamin medication, their general condition was rapidly restored to as nearly normal as possible. Attention was given to the proper clearing and attempted control of the bowels, and an intensive program was undertaken for the elimination of urinary infection and establishment of automatic bladder.

At first it was thought necessary to keep these patients in bed during treatment of their bladder conditions and to maintain the suprapubic cystostomies for long periods. Later it became apparent that they could be out of bed earlier than was previously thought possible and that the suprapubic drainage could be replaced by urethral catheter at an early date. The suprapubic drainage tubes were removed as soon as gross infection of the bladder had cleared up under irrigation. Suprapubic sinuses failing to close within two weeks after removal of the suprapubic catheter were surgically closed. Irrigations of the bladder at two-hour intervals were continued through the urethral catheter until cystometric examination revealed increasing capacity. At this time tidal drainage was instituted and was continued until automatic bladder function had been established. Roentgenologic studies were made regularly to discover any existing stones.

In the management of decubitus ulcers, we ran the gamut of local treatment, hoping to secure a separation of slough, clean granulation, and perhaps epithelization. Progress toward healing was slow under all types of local application.

Grafts of various sorts were tried, with little to choose between them in point of effectiveness. Eventually, it was discovered that it was possible to close some of these ulcerations effectively by suture. This came to be the method of choice wherever it could possibly be employed.

The ulcer was excised with complete undercutting of the skin and subcutaneous tissue with the formation of wide flaps. Closure of the defect was performed with tantalum or steel wire suture. Two layers were employed in closure, one for the deep fascia and one for the skin. The stitches were left in place for 21 days. Penicillin was used systemically both pre- and postoperatively. This plan of attack virtually superseded other methods of closure and sacral decubitus ulcers as large as 15 centimeters in diameter were successfully closed and healed. Of 52 such operations reported in our first group, 60 per cent of the bedsores closed by suture remained healed on the first attempt.

Regular exercising of the unparalyzed muscles of the upper body was carried on assiduously from the start, and as soon as the bladder and ulcer condition permitted, the patients were given special instructions in self-care and in walking. The orthopedic

section collaborated in the construction of appropriate braces and, with these applied, the patients attended classes daily for guidance, assistance and instruction. Special wards and messing, exercise, physical therapy and recreation facilities were provided for these patients, and an active program of rehabilitation, including work projects, was maintained.

Observations on a group of 67 patients suffering from spinal cord injuries were reported by the Neurosurgical Service. Three had cervical spine injuries, 46 dorsal spine injuries, and 18 lumbar spine injuries. Twenty-five per cent had incomplete paralysis with sufficient motor function of the legs to permit walking with braces. Only two of the complete paraplegia cases were of flaccid type. Twelve patients presented complete sympathectomy effects. Twenty showed increased sympathetic tone (with cold, moist feet). All but one had flaccid paralysis of the bladder. Three patients with priapism had contusion rather than transection of the cord. No case which on admission showed no flicker of motion in the foot or leg showed any improvement after one year of hospitalization. Only two cases of cauda equina injury which showed no flicker of motion on admission showed later improvement. In these 67 cases of paraplegia, 34 laminectomies had been done overseas, while 14 laminectomies were done in Cushing Hospital because of total manometric block or in order to determine prognosis and the justification for anterior root resection to diminish spasm. In these 48 cases subjected to laminectomy, the following findings were recorded: 14 cases, transection; 18 cases, normal appearing cords; 16 cases, contused cord.

Sixteen patients eventually improved and sufficient function developed to permit walking. The remainder showed no neurologic improvement in from one to twelve months. Yet even those who showed no neurologic improvement were brought to a tolerable and even a useful existence. In this significant fact lay the justification and the reward of the new attitude toward spinal cord injuries.

DR. LOYAL DAVIS, Chicago, Ill.: Doctor Kennedy has given an excellent description of the fine care which the paraplegia patients have received in Army hospitals. I can corroborate all his statements because I had the opportunity, after returning from overseas, to visit seven Neurosurgical Centers at the request of the Surgeon-General. In each place these patients received meticulous attention to every detail of their treatment and the Army Medical Corps assigned trained personnel whose duty it was to devote themselves to the care of these patients. For example, at one of the General Hospitals there were doctors, physical therapists, nurses, entertainers, and orderlies in such number that for each patient there was an average of one person with him throughout the 24 hours.

Now these patients have been transferred to the Veterans Administration, and rightly so, because they are, and should remain, wards of the Government. The advancement and knowledge of the surgical profession in the past 25 years has been so great that these patients have been kept alive, whereas in the last war they died. However, it must not be concluded that when they are discharged from the Army hospital to the Veterans Administration they are custodial cases. As a matter of fact, they are patients who will always require the most meticulous, painstaking and personal care. They will always be medical and surgical problems; they will develop decubitus ulcers, urinary bladder stones, urinary infections, and depression, unless they receive the same amount of care that they have had in the immediate past. The doctors of the Veterans Administration and the profession at large know how to treat these patients just as well as the Army has treated them, but the problem is to find personnel to give this care. Nurses, attendants, physical therapists are just as difficult to find for the Veterans Administration as they are for private hospitals. At the Veterans Administration Hospital at Hines, Illinois, where more than 300 patients have been transferred from the Army, it has been necessary to ask the Surgeon-General to transfer to Vaughan Hospital the personnel who can look after these patients with the same

standards of efficiency, until the Veterans Administration can supply personnel, which also includes doctors.

I believe that this is important, because the profession and the laity must be aware of the tremendous duty it has to these patients and because it is so easy for those who are politically minded to criticize the care of these patients in the Veterans Administration without knowing or attempting to find out the difficulties encountered in obtaining personnel to look after them. Finally, the profession and the laity must understand that not all patients who are paraplegics can be made to walk again. What can be done depends entirely on the level and the nature of the spinal cord injury. Unfortunately for these patients, the psychotherapy necessary for them has been over-emphasized and over-sold, to the point where there may very well be a very disturbing and bitter reaction upon the patient and his relatives.

DR. HOWARD C. NAFFZIGER, San Francisco, Calif.: The Army and Navy deserve great praise for the encouragement that has been brought to these most severely injured patients.

Much publicity has been given to ambulation and the benefits to the patients have, no doubt, been great. Ambulation for those with incomplete cord lesions or those with damage to low levels is in a different category from the complete lesions at the midthoracic level, or higher. In the latter, the benefits of ambulation are indirect ones. Strengthening of the musculature in the trunk and upper extremities, improving nutrition, and promoting psychologic adjustment to their situations have been promoted. In the group of those with high complete lesions, yet with intact innervation in the upper extremities, I should like to stress the importance of early occupational guidance. Experiences with such patients who have become self-supporting have emphasized its value. Occupation and restoration of earning power are prime factors in management.

DR. WILLIAM JASON MIXTER, Boston, Mass.: I have had a certain amount of experience in seeing these cases for the Surgeon-General, and it has been interesting to watch the advance in the care of paraplegics in the last three years. We were pretty badly discouraged at first. I believe a great deal can be done to help these patients. We have heard a good deal about the question of anterior root section for spasticity. This is a very valuable adjunct in treatment. But it is extremely important that anterior root section be withheld until we are perfectly sure there will be no return of power in the muscles.

DR. JOHN H. GIBBON, JR., Philadelphia, Pa.: I merely want to emphasize one point Doctor Kennedy did not have time to discuss—the psychologic readjustment of the patient to his physical condition. This readjustment is of great importance to the problem of nutrition. A man will not eat until he feels that the future holds something for him. Until the patient is convinced that life holds some promise of a place where he can be reasonably happy you are really licked on the problem of nutrition. There are two ways of getting psychologic readjustment rapidly. One is through the personality of the family doctor or the ward officer in the Army hospitals. If you have a doctor who is not interested and cheerful and encouraging you will not get to first base. If you have the right family doctor, patients will make the proper adjustment quickly. The second way of helping these patients is to use as an example one of the patients who has already become adjusted. We had one such patient in a large ward of paraplegic patients. He did more than anyone else, not excepting Gray Ladies, Red Cross, *etc.*, to improve morale. He went outside the hospital and worked at a mechanical job in a small plant for two hours every day. He thus gave a practical demonstration that a man with paralyzed legs could hold down a job. His cheerfulness and determination gave an enormous boost to the morale of the other patients.

DR. ROBERT H. KENNEDY, New York City (closing): Regarding the future problems of the veterans, I think nothing can be certain as yet. Many who now wish to go to their homes are going to find that they would prefer to remain in communities where there are others with similar injuries. Parents are anxious to have these men at home at first. In one Center with 130 patients, already about 40 have gone to their homes. This hospital expects to close June 30, and in the meantime they expect to have 30 more ready to go home, which will leave about 60 to transfer to Veterans hospitals. This shows the result of training. They are all given periods at home for at least a month before they are discharged, so that they may learn whether they wish to stay at home and that their families may know whether they want them.

So far as occupational therapy is concerned I think it is extremely important. I was much interested at one hospital in a factory for precision work. The men were allowed to work two hours in the morning and two in the afternoon; they had to punch a time clock and were docked if they were late. They were paid by the hour, and it was amazing to see the interest they took. Of course, that does not solve the problem later. I agree with Doctor Mixter that one has to wait at least a year before doing any destructive operation, not knowing how much return of function there may be.

# OPERATIVE RESULTS IN INTERVERTEBRAL DISKS*

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PRIOR TO 1930, pain in the lumbosacral region radiating down the leg was commonly termed sciatica or sciatic neuritis. With rest in bed, heat, leg-traction and other conservative methods, many patients recovered satisfactorily. Gradually the pain subsided, they resumed their original occupation or changed to lighter work, and, on the whole, did not do too badly.

The discovery that a sudden twisting injury to the lower spine could rupture the intervertebral disk, protrude it posteriorly, and, by stretching the underlying dura and compressing adjacent nerves, produce this low-back pain sciatic syndrome, cleared up at once the obscure etiology of many of these cases. Consequently, surgical removal of the disk was promptly suggested and widely heralded as the most certain means of assuring rapid and complete relief. Although the pain accompanying a ruptured disk can vary from decided discomfort to extreme distress, the condition of itself never resulted in a fatality. To advise surgery under these conditions, even when the operative procedure is as safe and simple as that required in the removal of a disk, brings up the definite question as to the expediency of operative intervention. With even the simplest surgery, unfortunate accidents can, and have, occurred. Following operative removal of the disk, will the patient be relieved of his discomfort so that he can return to work? What are the chances of failure to relieve the pain, or of an increase of disability, following surgery? It is high time that more emphasis be laid upon follow-up results after operation, than upon diagnostic methods and surgical technic.

While the literature is replete with information dealing with clinical signs, diagnostic methods and operative technic, but little is said about results.

A review of the literature reveals relatively few summaries of post-operative results. Verbrugghen[1] records 83 per cent successful in 75 cases. Shinners and Hamby[2] in 87 cases claim 50 per cent cured and 50 per cent with some residual pain in back or legs. Poppen[3] reports 65 per cent of 400 cases completely relieved, 35 per cent improved, although in 90 per cent of this latter group the sciatic pain was checked. In 60 per cent of his cases postoperatively, heavy lifting brought on low back discomfort. Jelsma[4] describes 90 per cent good results in 150 cases operated upon. Botterell and Keith,[5] and Gross[6] in handling military personnel were able to return 60 per cent and 70 per cent, respectively, to full duty. McKenzie and Botterell[7] in 57 cases report 48 excellent and nine fair results. Barr and Mixter[8] showed 77 per cent complete relief. In Camp and Love's[9] series, 66 per cent of 50 cases showed a highly satisfactory result. Craig and Walsh[10] differenti-

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ate their results in compensation and noncompensation cases, a highly important point. In noncompensation cases, in 83.3 per cent results were satisfactory as against 59.1 per cent in the other group. Adson[11] in making the same separation rated 90 per cent of his noncompensation group as satisfactory, the percentage falling to 77 per cent in the compensation cases. Keegan and Finlayson[12] show, roughly, 75 per cent satisfactory and 25 per cent poor results. Smith and Deery[13] in 70 cases record 34.3 per cent excellent and 45.9 per cent good results. So it can be seen that while, by and large, the results are fairly successful, nevertheless, the surgical removal of a ruptured disk does not necessarily result in complete relief of pain.

Pain produced by a ruptured disk has two components, the pain in the back and the pain in the leg. Back pain is the initial complaint followed by pain radiating down one leg. Leg pain in the sciatic distribution leads to the suspicion or certainty of a ruptured disk. Pain in the back is due to pressure on, or rupture of, the posterior vertebral ligaments. Pain down the leg is caused by the protrusion of the disk against the adjacent lumbar nerve roots. These two pains are different components of the same progressive picture, and both are important in its recognition. Why does the disk rupture? Trauma, a twisting wrench of the lumbar vertebra, is a commonplace finding in many histories. But in other instances, a no more serious injury than rolling out of bed has been noted. Does the disk rupture because of some structural disability of the back and is the low back pain the earliest clinical evidence of such weakness? This point, I believe, is very important, because while by removal of the disk the leg pain is almost always relieved, the pain in the back may remain and produce discomfort and disability.

It is necessary to state here that, while we are convinced that these two pain components exist and for different reasons, as outlined, we have had no experience with fusion as a means for relief of the back pain following improvement or relief of the leg pain by removal of the disk. It is hoped that the indications for, and results of, fusion will be one of the points brought out in the discussion.

This paper deals solely with the results following surgical removal of an abnormal intervertebral disk in 200 cases. The follow-up period varies from 6.5 to 1.5 years, with an average of just over three years. No case operated upon since January 1st, 1945, has been included, so that sufficient time has elapsed to determine with some accuracy the final result. These 200 cases represent replies to a questionnaire sent out to 275 cases. In addition to the questionnaire, some 150 cases reported in person.

In reviewing these 200 cases, attention was centered solely on one group of facts; what was the patient's condition prior to surgical intervention and to what extent was he benefited by the operative procedure. Preoperatively, 72, or roughly 35 per cent, were suffering so much back and leg pain that they were bedridden; 104, or 55 per cent, were unable to work and 24, or 10

per cent were working, although under considerable distress. As a result of surgical procedures, the following results were noted. One hundred and twenty-seven cases, or roughly 63 per cent, were completely relieved of all pain; 58, or 29 per cent, were improved and 15, or 8 per cent, were unimproved or worse. Since the type of work which these patients were performing when the injury to the back occurred, and especially the occupation they must resume postoperatively, and the amount of strain to which the lumbosacral area will be subjected is of critical importance in estimating the ultimate outcome, these figures were further broken down. Among these 200 cases, 98 were laborers: miners, farmers, shipbuilders, nurses, and 102 were nonlaborers: clerks, executives, professional men, housewives. Interestingly enough, the division between laborers and nonlaborers is nearly equal. Hard labor, of itself, does not seem to be a predisposing cause for ruptured disk. In the group of 98 laborers, 57 were completely cured, 57 per cent, 37 were working with some disability or had changed to lighter work, 37 per cent, and four were unimproved, 4 per cent. Among 102 nonlaborers, 69 were entirely relieved, 68 per cent, 20 improved, 20 per cent, and 13 unimproved, 12 per cent.

What is the effect of the degree of protrusion of the disk; complete rupture, simple protrusion or the so-called hidden disk, upon the operative results? A definition of what is meant by these three varieties of disk is indicated. Frequently a disk is exposed which has actually commenced to extrude itself into the canal, so that without incision of the annulus it may be seized and withdrawn, or the nerve may be humped over it and retraction of the nerve to either side is followed by an immediate greater or smaller amount of protrusion. This is our conception of a completely ruptured disk. Secondly, a protruded disk represents a situation where the annulus is obviously protruded posteriorly by the disk, and when once the annulus is opened, prompt spontaneous emergence of the disk occurs. Lastly, a hidden disk produces little or no protrusion of the annulus, although the overlying spinous process shows an increased mobility, the adjacent root is slightly swollen, and palpation over the annulus reveals some relaxation. Incision of the annulus and curettage of the disk suggests that softening and degeneration have occurred.

In this series of 200 cases, 49 had a cleanly ruptured disk; 26 laborers, 23 nonlaborers. Twenty, ten laborers and ten nonlaborers, were bedridden by the pain; 23, 13 laborers and ten nonlaborers, were unable to work and six, three from each group, were working with some disability. Forty-two myelograms were carried out in this group and all showed definite evidence of the presence of a disk. Following removal of the disk, 39, 80 per cent, 20 laborers and 19 nonlaborers, are completely relieved; nine, six laborers and three nonlaborers, are completely relieved of leg pain, 18 per cent; but have in eight cases occasional slight, and in one, moderately severe back pain, while only a single patient is entirely unimproved, 2 per cent. In an average follow-up of 3.6 years, a single case has had recurrence of pain.

One hundred thirty-one patients had protrusion of the disk, 65 laborers and 66 nonlaborers. Forty-seven, 21 laborers and 26 nonlaborers were bedridden. Sixty-nine, 36 laborers and 33 nonlaborers, were unable to work, and 15, eight laborers and seven nonlaborers were working with some disability. Following removal of the disk, 77, 35 laborers and 42 nonlaborers, were entirely relieved of pain, 59 per cent; 44, 28 laborers and 16 nonlaborers were completely relieved of their leg pain, 34 per cent, but 18 of the 28 laborers had shifted to lighter work because of renewed back pain, and six of the 16 nonlaborers had occasional periods of lumbosacral discomfort. Ten patients, three laborers and seven nonlaborers, were unimproved, 7 per cent. In an average follow-up of this group of 3.5 years, five patients, three laborers and two nonlaborers, have suffered a recurrence of pain similar to their original attacks.

Twenty patients had "hidden" disks, eight laborers and 12 nonlaborers. Six, two laborers and four nonlaborers, were bedridden, 12, six of each group, were unable to work and two nonlaborers were working with some disability. Following surgical intervention, 11, three laborers and eight nonlaborers, were completely relieved, 58 per cent; four, three laborers and one nonlaborer, had occasional disability, 21 per cent; and five, two laborers and three nonlaborers, were not relieved, 21 per cent. In an average follow-up of four years, two nonlaborers returned with definite evidence of a recurrence.

Broadly speaking, our figures seem to confirm the impression gained from clinical experience that the greater the amount of preoperative pain, the better the final result. It is also interesting to note that of the 17 failures, nine had had but one attack of pain prior to operation. At present, no patient suspected of having a ruptured disk is considered for operation unless he has had two attacks or more of pain and unless the pain is severe at the time he presents himself in clinic. To operate upon a patient who has had his attack and whose pain is definitely receding is unwise. All these persons will have some distress for a longer or shorter period postoperatively. If they have had a great deal of pain preoperatively, this postoperative readjustment period means little to them. Their major pain is relieved and the mild postoperative pain is readily accepted. But if the preoperative pain is mild, particularly if the surgeon has been unwise enough to promise complete relief, then this postoperative pain discourages them; they feel the operation has been a failure and the final result is much less satisfactory.

In the course of this review, two other groups of cases were encountered, 29 patients operated upon for disk in whom no disk was found, and 44 cases in whom, who although clinically, and in 33 further confirmed by myelography, an intervertebral disk seemed unquestionably present, for various reasons no operative procedure was carried out. In the operated unverified group of 29, 17 were laborers and 12 nonlaborers. Nine were bedridden, 17 unable to work and three were working with difficulty. Following operative exploration without removal of a disk, 14, ten laborers and four nonlaborers, were entirely relieved, 48 per cent, eight were working with some disability

or changed to lighter work, 28 per cent, and seven were unimproved, 28 per cent. These figures parallel very closely the "hidden disk" group, into which category it seems quite possible that many of these cases might well fall. The average follow-up was four years, and none, as far as is known, has had a recurrence. The disk suspects unoperated comprise 44 cases, 21 laborers and 23 nonlaborers. Thirteen, four laborers and nine nonlaborers, were bedridden; 15, ten laborers and five nonlaborers were unable to work, and 16, seven laborers and nine nonlaborers were working with disability. Under conservative treatment only: ten, three laborers and seven nonlaborers were completely cured, 23 per cent; 18, ten laborers and eight nonlaborers, were improved sufficiently to work at lighter jobs, 41 per cent; nine comfortably and nine with occasional mild pain, and 15, ten laborers and five nonlaborers, were unimproved, 36 per cent. Three of these last patients were operated upon elsewhere some time within the four-year average follow-up for this group.

That in all of the patients in this nonoperated group, a recurrence, or severe increase in pain, can occur at any time, if they are unlucky enough to twist or wrench their backs, is of course admitted. Removal of the disk may then be carried out. Although this is a relatively small group of cases, that recovery has occurred under conservative treatment alone should be remembered.

As a result of this review of the results of the surgical removal of a ruptured disk, we see no reason to change the conservative attitude we have adopted in the past years. Pantopaque myelography should always precede operation to show the size and position of the disk and whether more than one exists. Curiously enough, we have never seen a double disk, although Dandy[13] has stated that they are not uncommon. If myelography shows a large disk, if the pain is severe, and if the patient has had previous attacks, surgical removal of the disk is indicated. But surgery is not, in our opinion, the only treatment for this condition. The question as to whether surgery is expedient should always be considered. Many of these patients will recover with rest, leg traction, a back brace, and other nonoperative methods. Nature will care for many of these sufferers exactly as was the case prior to 1930. It seems presumptuous of the surgeon to interfere until he has given nature every chance. The results from surgical treatment do not seem sufficiently good to warrant it.

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DISCUSSION.—DR. WILLIAM JASON MIXTER, Boston, Mass.: In the first place, I should like to thank Doctor Grant for bringing up this subject at this time and for giving us a very keen evaluation of his results, and for asking certain questions which, at the present time, I do not think we are able to answer. So far as I know there has been no complete study made of the results on a large group of cases of intervertebral disk, carrying out the criteria he has asked for. I think we are all trying to carry that out at the present time, and hope the answer will be forthcoming. We may be able to answer that question at the meeting of the Orthopedic Association next June, when the problem is to come up again. I think we must depend to a considerable extent on the Army and Navy for evaluation of the problem of ruptured intervertebral disk. The enlisted man has been a very unsatisfactory patient upon whom to do surgery.

There are one or two points to mention. Doctor Grant says this operation is done for relief of pain and that no fatalities have occurred from letting patients go. Fatalities do occasionally occur from letting patients go, because they get an acute transverse lesion which results in death from sepsis unless relieved. Patients have paralysis and foot drop if the lesion is allowed to persist for any length of time, and the foot drop does not come back.

I cannot answer the question about fusion. We are looking up these cases at the present time, and we have in Boston a more or less parallel series and may be able to answer some of the questions. My own impression is that patients who have to do heavy work, laborious work, postoperatively, and where there is definite and abnormal mobility demonstrable at the time of operation, probably should have fusion done. Doctor Grant's criteria for operation I believe are accurate and I would subscribe to them. I would also subscribe to the dictum not to operate upon patients who are recovering from an acute attack and are pretty well. They are better operated upon in an acute attack. I believe that real ruptured disks with extrusion are the ones in

which you get the best results. The patients with a bulging disk margin or softened disk margin do not give nearly so good results.

Dr. George E. Bennett, Baltimore, Md.: Last evening Doctor Grant handed me a copy of his paper and, after reading it and listening to his intelligent discussion, I believe it is about the most sane presentation of this important subject that I have yet read or heard. There are, without question of doubt, a great many cases of sciatic pain associated with intervertebral disk injury which demand operation, and the end-results are very satisfactory. There is another group of congenital abnormalities of the facets with secondary degenerative change in the intervertebral disk and subsequent nerve pressure, which require not only removal of the débris in the spinal canal but also a fusion of the vertebral bodies in order to effect a cure. There are also a great many cases of sciatica which are not the result of pressure on the nerve root from degeneration of the intervertebral disk, such as in Strümpell-Marie arthritis, where the change is about the facet with associated pressure from inflammatory reaction, which usually clears up with time.

Many years ago in discussing this subject with Doctor Mixter I asked him the indications for operation. His reply was: "After you have tried all the orthodox methods of treatment for sacro-iliac strain and lumbosacral lesions and your patient is not relieved then you should consider an intervertebral disk, and after thorough study operation might be suggested."

I feel that Doctor Grant has posted a sign such as we see at a railroad crossing—"Stop, Look and Listen!"

Dr. James C. White, Boston, Mass.: It may be of interest to summarize a series of 24 sailors and marines who had lumbar intervertebral disks removed at the U. S. Naval Hospital in Chelsea, and were then carefully followed for from six months to two years. So far as I know, there are practically no studies on military personnel who have had this operation. The Bureau of Medicine and Surgery of the Navy was extremely coöperative and followed-up these patients all over the world. Of nine officers returned to active duty, eight have remained in this status to date. One who fell in a foxhole and gave his back a wrench came back subsequently to the hospital needing a spinal fusion, which was done. Of 24 men and officers, 75 per cent, after periods of over five months, were on full duty or on limited duty with the expectation of returning to full duty; of the remaining 25 per cent, one has been a total failure and fusion has not helped. Two have returned to the hospital with recurrence. Both of these men had been doing too heavy work, one shoveling snow and the other handling heavy mess trays. Two others were last heard from on limited duty but not completely free of symptoms. So you have about 75 per cent in whom it looks as if the operation had been effective from a military standpoint. They all had preliminary orthopedic treatment and were submitted to us after that had failed. Only definite disks were operated upon and the more definite the disk the better the result. One had an obstructive disk with paralysis of the bladder; he was a football player, and ne played football three weeks later, unknown to me. He has done well. In contrast, in another hospital where we could not give as satisfactory preliminary orthopedic treatment, the results, I am sure, are not going to be so good.

Dr. Philip D. Wilson, New York City: There are many aspects of this problem that could be discussed, but I should like to speak only on one or two points. In the first place, I believe that myelograms are generally helpful in dealing with fresh cases. Since pantopaque has been made available to civilian hospitals we have had excellent results in employing it and have always been able to remove it afterwards through the needle. If this technic is followed I do not believe that it could be harmful, and we need all possible information not only in making the diagnosis, but also in localizing the lesion. I have seen a good many cases, however, that have been operated upon

previously, where the disk has been removed, without relief of symptoms. In such cases I believe that the myelograms may be very deceptive and that old extradural adhesions, together with the absence of the ligamentum flavum, may distort the picture. I think this point should be borne in mind in making studies on such cases.

The second point is as to the place of the fusion in treatment of disk protrusion. Should fusion be done in every case in which the disk is removed? I do not think so. There is no doubt that when we combine fusion with disk removal we increase the severity of the operation. We have to secure a much larger surgical exposure for such a procedure than when the disk alone is removed, and, in addition, there is always prolongation of convalescence required by the necessity of having to immobilize the spine in order to obtain solid fusion. I believe that fusion should be done when there are associated spinal lesions which of themselves might produce symptoms, and I think fusion should also be done when we fail to find a satisfactory explanation of the pain after inspection of the disk; otherwise, I believe fusion should be reserved as a secondary procedure to be done when disk removal fails to give relief. From Doctor Grant's figures we can see that this group of cases is going to be relatively small. Furthermore, I believe that in the cases where we find a soft bulging disk without actual protrusion, fusion should be done. I cannot believe that even complete curettage of the disk will be followed by such complete fixation of the adjacent vertebrae as to guarantee freedom from pain. I have made roentgenologic examinations of several cases in which this procedure has been done by able surgeons and, by taking films in flexion extension, or in different positions of lateral extension, have been able to demonstrate that motion still existed between the two vertebrae. This motion was limited, to be sure, but not sufficiently so to prevent pain.

I believe that it is important for the orthopedic surgeon to attempt to shorten the convalescent period of the patients in whom fusion is done. I think this can be accomplished by the use of internal fixation in the shape of a plate bolted to the spinous process, combined with the bone graft. Fixation of the articular process by screws is another method of accomplishing the same thing, but gives less solid fixation than the plate. When we use internal fixation it is possible to get the patients out two weeks later with the support of a brace.

I wish to congratulate the speaker on his very careful study of his cases, one of the most careful that has yet been made. I think his method of comparing his results with the preoperative condition is a real contribution, and the facts he has brought out are very satisfying so far as the results of treatment are concerned.

DR. WILDER PENFIELD, Montreal, Quebec: This is a field that has become important within a short time. In 1939, when the International Neurologic Congress was held in Copenhagen, it was proposed that a paper be given on ruptured intervertebral disk, and the statement was made that there was no such thing. Doctor Mixter, as was proper because of his pioneer work, described protrusion of the intervertebral disk for the first time then on the continent of Europe.

A great many men are operating upon these cases without serious study, and I am sure the incidence of success cannot be so high as that of Doctor Grant. We feel that all cases should be studied by pantopaque. We find that very frequently the sciatica is cured, but not the back pain. The patient whose sciatica is not cured should be studied further, and reconsidered. Many people have more than one disk protrusion, and how it is possible to make a diagnosis without complete study, simply on reference of pain, I am at a loss to know. There is the unsettled question as to when fusion should be combined with removal or used as a sequel. The question of whether the facets should be curetted at the time of removal of the disk has yet to be decided.

I think that patients in whom we are not successful should be brought back for further study and myelography—they can be cured.

DR. MAX PEET, Ann Arbor, Mich.: We believe that all patients with a possible herniated disk should be carefully studied from the orthopedic standpoint as well as from the neurologic one. There is certainly no excuse for a hasty diagnosis. I agree with Doctor Grant in much that he has said, but do differ on one particular point. We have discontinued using pantopaque in the majority of cases. Very rarely do we now perform myelography; only in those cases that are questionable have we thought it was indicated. For example, if a differential diagnosis between a cauda equina tumor and a herniated disk seems necessary, pantopaque, of course, should be used. We also perform myelography in patients with a rather clear-cut history of a herniated disk, but with negative findings on neurologic and orthopedic examinations. We have two reasons for the elimination of myelography in the majority of patients: First, in the typical case a definite diagnosis can be made on history and physical findings; second, we have found that there is a factor of error in myelography. We have had patients with perfectly definite evidence of a disk on myelography, and at operation no herniation or protrusion was found and, conversely, we have seen negative myelograms and at operation have found a large herniated disk.

We have been impressed with the modification of the usual symptom complex shown by a number of patients. These gave a history of the usual primary backache, followed some time later by sciatic radiation of pain with a subsequent disappearance of the low backache, but a persistence and, in many cases, a marked increase in the pain radiating down the leg. I had not thought of the significance of this until Doctor Badgley of our Orthopedic Department pointed out to me that every one of these cases had had a complete protrusion of the herniated nucleus pulposus, which was found to lie free under the dura. I think this may be the explanation. The loosened disk had completely herniated and lay loose, either above or below the disk space, thus, relieving pressure on the nerve endings in the posterior annulus fibrosus and posterior longitudinal ligament. It seems a reasonable assumption that it is pressure upon these particular nerve endings which gives backache when a disk is protruded. Recently, in a patient showing this modification of the symptom complex, I found the disk space clear, but the completely ruptured nucleus pulposus had slipped down into the upper sacral canal and was wedged against a sacral nerve. Had there not been a few strands of the nucleus protruding from beneath the dura, I might have missed it.

We believe spinal fusion is indicated in comparatively few patients with herniated nucleus pulposus. At times we have recommended fusion when great mobility of the vertebrae was found at the time of operation. We have also recommended it in patients who had persistence of backache although the leg pain had been removed by excision of the disk. We are opposed to fusion operations in cases of suspected herniated disk, since we have had to operate upon some cases for a persistent pain due to a ruptured disk with protrusion of the nucleus when a successful fusion had already been accomplished. This makes the operation considerably more difficult.

DR. FRANCIS C. GRANT, Philadelphia, Pa. (closing): I am very much obliged to the various gentlemen who have taken the time to give this subject their consideration, particularly Doctor Bennett and Doctor Wilson. There is one group of cases that one meets in handling patients with a ruptured disk that we have not had time to cover in any detail. Those are the cases in which the disk injury is produced while the patient is at work and where the question of compensation plays a part in the general situation. When compensation is a factor it is unquestionably more difficult to obtain a satisfactory result than in those cases in which compensation is not a major consideration.

Doctor Mixter has spoken of the occasional emergency case in which there has been rather abrupt interference with bladder function. Under these circumstances, of course, an immediate laminectomy is indicated. However, the cases who have obviously a disk, and in whom a foot drop occurs, are not, in my opinion, necessarily in

need of immediate surgical intervention. I have seen three of these cases who developed a complete foot drop, and the foot drop finally recovered spontaneously without operative intervention.

I agree with Doctor Wilson and Doctor Peet about myelography. We carry it out in the great majority of our cases because it tells us something of the size of the disk. As was noted in the first group of cases, it was our experience that the larger the disk the better the ultimate result. This information can be obtained from myelography. Pantopaque should always be used because it can be removed later. We find, on the whole, that the clinical symptoms are a better guide to the necessities of the case than are the myelographic findings. However, in a patient who has relatively few symptoms and a negative myelogram, no surgical intervention, of course, would be indicated. I feel that myelography is useful and, after one has had experience with it, of considerable value.

# PENETRATING WOUNDS OF THE CHEST IN THE PACIFIC AREA*

## AN ANALYSIS OF 180 CASES

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THE PRIMARY OBJECT of this study was a critical review of the care of a group of wounds of the chest from their inception to final disposition. The follow-up phase of this study was at times difficult, and was made possible only through the fine coöperation of the U. S. Marine Corps, the Navy Department, the Veterans Bureau, and personal communiques from the wounded.

The care of penetrating wounds of the chest sustained in the Pacific Theater was of necessity modified from time to time due to the changing conditions in that area. The island-hopping operations, the character of the terrain, and the great distances between advanced bases prevented segregating the early casualties into specialty groups and despatching them to designated hospitals.

To offset early difficulties in the care of patients, specialty teams were formed by the army and navy, their purpose being to serve in the combat zone, augmenting and guiding the existing medical personnel during the more active phases of fighting. It soon became apparent, however, that in injuries to the chest little definitive care of major importance could be provided in the forward dressing station or even in the field hospital without adequate roentgenographic studies, without closed endotracheal anesthesia, and without special equipment so necessary in doing definitive work on this group of patients.

It, therefore, became expedient to train the doctors and the corpsmen in the forward combat zones in the immediate or emergency care of the chest wounds.

The following specific emergency measures were stressed:

(1) The initial care of the sucking wound by the application of a large sterile gauze or vaselined dressing and firm strapping.

(2) The recognition and care of a tension pneumothorax by the insertion of a short-beveled No. 15 needle, with finger cot attached, in the second or third interspace two fingers' breadth to the left or right of the sternum, supplemented by the substitution of an intercostal catheter if the needle did not suffice. In this series a tension pneumothorax was encountered in three cases. A catheter was resorted to in one instance. It was removed on the fifth day without incident.

(3) The detection of rib-cage instability and the simple means of affording relief (a) by having the patient placed on the affected side; (b) by strapping the affected side; (c) by the injection of the intercostal nerves; and (d), when

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necessary, providing some means of external support. In our series this condition as a distressing factor presented itself only on two occasions and was adequately handled by firm strapping and by placing the patient on his affected side.

(4) The gravity of a progressive mediastinal emphysema was discussed and a suprasternal incision with tube drainage advocated. Only one case in this series required surgical relief. A tracheotomy tube was introduced into the soft tissues of the suprasternal notch paralleling the trachea. After a few days the wound in the trachea sealed-off, and the tube was removed from the soft tissues without incident.

(5) Small repeated aspirations without air replacement were recommended for progressive hemothorax when respiratory difficulty became alarming. Except when progressive bleeding was definitely coming from the chest wall, this procedure together with the various supportive measures sufficed to permit stabilization.

In addition, a few general measures were stressed as part of the patient's emergency care: (1) Morphine in moderation. (2) Maintaining a clear airway. (3) Administration of intranasal oxygen. (4) Administration of whole blood, plasma, or serum albumen, the amount and rapidity of administration being dependent on the degree of moisture in the lungs, and on the absence of increased venous pressure. (5) The use of an intranasal gastric tube if a thoraco-abdominal injury was suspected. (6) The optimum position of the patient was determined by the presence of severe hemoptysis, degree of shock, and stability of the affected rib-cage. Some patients were more comfortable with head and chest slightly elevated, and usually respirations were less labored with the patient on his back and inclined toward the affected side.

Certain interesting facts were recorded in their histories. In the earlier campaigns, where most of the fighting was in the jungle, a relatively high number were struck by sniper bullets when lying prone or in a kneeling position. Later, many were injured while standing erect. In the final analysis, 68 were standing when struck, 45 kneeling, and 44 lying prone.

Only 31 stated they were unconscious, and 13 used the term "dazed." One hundred and twenty-six stated they did not lose consciousness. In those who survived, severe hemoptysis was a very rare complication. A small amount of blood was raised by 97. The remaining 73 raised no blood at any time. The frequency and severity of pain, cough, and dyspnea varied considerably, as would be expected. For the most part, these patients stabilized in a forward station or aboard ship in the first few days. Chemotherapy was administered almost routinely, in the early campaigns in the form of one of the sulfa drugs, later augmented by penicillin. Elective aspiration or elective surgery was usually carried out at a secure rear base hospital.

Of the 180 cases, ten died. Eight deaths were immediate or within a few days, and two late deaths occurred after return to the U. S. A.

BRIEF CASE SUMMARY OF DEATHS

Case 1.—Portal of entry wound only. Missile—shell fragment. The missile penetrated the left lower chest imbedding itself in the diaphragm in such a way that one sharp spicule penetrated the pericardium, making contact with the tip of the left ventricle, with resultant hemopericardium, tamponade, and subsequent signs of right heart failure. This patient survived four days following injury.

Case 2.—Through-and-through, thoraco-abdominal sucking wound. Missile—bullet. This patient bled severely from his wound. On date of injury local packing of the wound was not sufficient to control bleeding. Later the same day open thoracotomy was performed and lower left pleural cavity packed. Four days following injury the stomach was found to be in the chest, and on the fifth day the patient was reoperated on board ship. The spleen which was lacerated was in the chest and was removed, the stomach replaced, and the diaphragm repaired. The patient developed generalized abdominal distention on the fourth postoperative day and died on the sixth as a result of generalized peritonitis and left pyopneumothorax. Infection had spread through a small defect in the diaphragm.

Case 3.—A through-and-through thoracic wound. Missile—bullet. The bullet traversed the right auricle in its line of flight. Patient was dead within 15 minutes as a result of rapid exsanguination into pericardium and right pleural cavity.

Case 4.—Portal of entry wound only. Thoracic. Missile—shell fragment. Died within a few minutes of injury. Autopsy revealed a through-and-through wound of the left ventricle with an hemopericardium under pressure. Death from severe hemorrhage with cardiac tamponade.

Case 5.—Portal of entry wound only. Thoracic. Missile—bullet. Patient lived seven hours. Bullet entered right chest shattering the second rib. Some rib fragments were found in the lacerated lung tissue at the postmortem examination. Patient went into immediate shock, with blood pressure 84/46. Pulse 128. Respirations 30. Air was aspirated from right chest, but continuous drainage was not afforded. He developed an emphysema from the face to the scrotum. Autopsy finding revealed a lacerated upper lobe with division of bronchus three millimeters in diameter. Right pleural cavity contained air and approximately 1,000 cc. bloody fluid. Death was the result of hemorrhage and tension pneumothorax.

Case 6.—Portal of entry wound only. Thoracic, sucking wound. Missile—bullet. Patient lived approximately 15 hours. He was in shock on entry to the hospital, blood pressure 84/60. There was no hemoptysis. Wound of right thorax was dressed. After few hours 450 cc. dark blood and 600 cc. air were aspirated from right chest. Oxygen was administered, but patient died. At autopsy, second, third, and fourth ribs were found to be fractured. There was a large laceration of right upper lobe. The bullet was found in the left upper lobe. There was approximately 1,500 cc. blood in the right thorax. Abdomen negative. Death from exsanguination.

Case 7.—Through-and-through wound of right chest. Thoraco-abdominal, with two sucking wounds. Missile—bullet. The sucking wounds were closed. Oxygen administered. Twenty-four hours later patient became worse. The heart seemed displaced to the left. Six hundred cubic centimeters of sanguineous fluid removed from the right pleural cavity. Patient given 1,000 cc. of blood and 1,000 cc. of plasma. Bleeding thought to be from an intercostal vessel. An excircling suture was placed in endeavor to stop it. Shortly thereafter he vomited an enormous amount of fluid and died. Autopsy findings revealed a large ragged hole in the right diaphragm through which some lacerated liver tissue protruded. The right lung was collapsed by 1,500 cc. of bloody fluid in right pleural cavity. There had been bleeding from fractured ribs, intercostal vessels, lacerated diaphragm, and liver. The acute dilatation of the stomach probably played a rôle in his death.

Case 8.—Portal of entry wound only. Thoraco-abdominal. Missile—bullet. The bullet entered the left chest in the anterior axillary line opposite the fourth rib. Abdomen was tender and rigid in all quadrants. The direction of wound indicated probable intra-abdominal injury. In spite of 1,500 cc. of plasma and 500 cc. of blood, patient died within

two hours after entry. At autopsy, fecal material escaped from the wound of entry. There were fractures of the seventh, eighth, and ninth ribs laterally, a small laceration of the left lower lobe, a large rent in the diaphragm, a large hole in the stomach, two large holes in the transverse colon and a small perforation of the jejunum. There was 2,000 cc. of blood in the abdominal cavity and approximately the same in the left thoracic cavity. Death from exsanguination.

Case 9.—Multiple portals of entry. Wounds along left thorax and left flank, which were considered as thoraco-abdominal. Missile—hand grenade fragments. The chest was treated conservatively. An emergency celiotomy was performed on the day of injury. The spleen was removed because of a through-and-through laceration. A large retroperitoneal hematoma was noted, but the kidney contour appeared normal. During convalescence overseas, a pyuria was present, and some deformity of the left kidney pelvis was noted. He was returned afebrile and ambulatory to the U.S.A. A few days after arrival at a West Coast hospital he died from a sudden hemorrhage from the injured left kidney.

Case 10.—A through-and-through wound. Thoracic. Missile—bullet. The wound involved the left chest and left shoulder girdle. The injury was not remarkably different from many others. He received some initial whole blood and plasma, but no excessive amount was required. The chest was aspirated on the third day because of difficult breathing, and two or three times during the subsequent two to four weeks. He was returned ambulatory and afebrile to the U.S.A. Eleven weeks following his injury, while convalescing, he suddenly developed a fulminating acute hepatitis and died in four days. All supportive measures were of no avail. Autopsy revealed only acute hepatitis.

In retrospect, it is fair to state that of the eight early deaths Cases 1, 2, 5, and 7 might have survived if it had been possible to examine more carefully and to evaluate properly all existing conditions. The two late deaths were unpredictable and unavoidable.

Of the 170 survival group, 134 were considered as thoracic wounds, 36 as thoraco-abdominal wounds, and 22 as sucking wounds. Eighty-eight were through-and-through wounds and 82 had portal of entry wounds only. The causative agent was as follows: bullet 96 cases; bomb, mortar, or shell fragment 60 cases; grenade fragments 12 cases, and bayonet two cases.

In the Pacific Theater, under the existing conditions, early aspiration was recommended only as an emergency measure for relief of respiratory distress and was done without air replacement. In this series it was resorted to in 17 cases in the first 72 hours. Elective aspiration, for the most part, was done aboard a well-organized hospital ship or at a secure rear base hospital. In 80 cases elective aspirations were performed during their convalescence, and in 87 no aspirations were performed.

In this series we have classified 36 as having thoraco-abdominal wounds. Eighteen were considered through-and-through wounds and 18 portal of entry wounds only. Nine major emergency operations were performed, six consisting of exploratory celiotomies and three of major explorations of the wounds of entry. There were 18 elective operations in this group. Ten were performed overseas and eight after returning to the U. S. A. The complications encountered were: empyemas, seven; kidney laceration or contusion, six; diaphragmatic hernia, three; subdiaphragmatic abscess, two; subdiaphragmatic bleeding (severe), one; and intercostal neuralgia (severe), three. The final disposition

of this group was as follows: To duty overseas, four. Returned to the U. S. A., 32. In the U. S. A. 13 returned to a duty status, and 12 received medical surveys because of thoracic lesion; and seven received medical surveys primarily because of nonthoracic disabilities.

Empyema developed in 20 cases. Twelve were considered thoracic wounds, seven thoraco-abdominal wounds, and seven of the 20 had sucking wounds. Bronchial fistulae were demonstrated in five of these cases. Ten cases were through-and-through wounds, and ten were portal of entry wounds only. The bullet was the causative agent in ten, mortar shell fragment in six, and grenade fragment in four. Foreign bodies were removed from the pleura in four, and from the liver in two. One empyema developed following repair of a diaphragmatic hernia and one empyema developed following a pneumonia on the good side, the penetrating wound and hemothorax being on the opposite side. All received chemotherapy in one form or another. Three were treated and successfully converted from positive to negative culture by repeated aspirations and penicillin administered intrapleurally and intramuscularly. Retarded expansion was noted in all three, one requiring a subsequent thoracoplasty. In three, initial intercostal drainage was performed followed later by rib resection. In 12, a small rib resection was done using a tube with finger cot attachment for drainage, thus, providing a semiclosed type of system which permitted early ambulation. In four, an Eloesser skin-to-pleura flap drainage was instituted. Three of these had bronchial fistulae. One drained adequately from the lower border of his operative wound. All 20 were returned to the U. S. A. for further convalescence. Two required additional local drainage in the U. S. A. Two had minor plastic procedures on resultant scars. Three required serial thoracoplasties to obliterate residual space. Two of these had large bronchial fistulae. The third was one of the cases treated by repeated aspiration, with conversion but retarded expansion. Of this group of 20, 15 received a medical survey, 13 because of the chest lesion and two for nonthoracic lesions. Five returned to a limited or full duty status.

*The Removal of Foreign Body:* Of the 82 cases having portal of entry wounds only, two had their foreign bodies removed during an emergency procedure, as the foreign body lay in the proximity of the operative wound. In 23, foreign bodies were removed as elective procedures overseas and three in the U. S. A. One patient passed his bullet per rectum. The foreign body was removed from the chest wall in 11, from the pleural space in six, from the lung in four, from the mediastinum in two, and from the liver in two.

The remaining 84 cases who were returned to the U. S. A. had very little surgery after their return. One bullet was removed from the pleura, one received a thoracoplasty for incomplete expansion, two received a semiclosed type of drainage for encapsulated residual hemothoraces, and two had intercostal nerves explored for persistent intercostal neuralgia. No pulmonary suppurations were encountered in any of this group. No late pleural suppuration was noted to occur in any of this group after return to the U. S. A. Two of the cardiac complications were of interest. One case developed an

extensive pericardial effusion two or three weeks after injury. It gradually receded without aspiration. The patient is clinically quite well and working. The second case developed an adhesive pericarditis within three weeks of injury. This case had a large metallic fragment in the interventricular septum. At operation for its removal, it was thought best to leave it alone because of the depth in which it lay in the interventricular septum and also for fear of additionally injuring an already thinned and weakened postventricular wall. The patient has been perfectly well and working for over a year. He has no symptoms referable to his foreign body.

In considering their disposition one might add that over 150 of the survival group were Marines. This factor of course accounted for the relatively high number receiving medical surveys in the U. S. A. The Marine Corps would often recommend a medical survey rather than having the patient return to a limited duty status. Of the 170 survival group, 112 were returned to limited or full duty. Of this number, 34 returned to duty overseas. Of the 78 returned to duty in the U. S. A. seven later reëntered a hospital and were later surveyed. Twenty-four received medical surveys for nonthoracic disability, the chest condition having cleared. Forty-one were surveyed mainly because of their thoracic injury. Of this latter group, 28 are now receiving pension; nine, rating a 100 per cent disability; one, 80 per cent; one, 60 per cent, six, 50 per cent; and 11, less than 50 per cent.

An analysis of the 41 cases relative to their working ability at the moment reveals that three are attending school as provided for in the G.I. bill of rights; 23 are known to be employed; nine state they do not feel able to work at this time; and six did not reveal their working status.

## SUMMARY

In summary, one may say that the thoracic wounds as a whole adapted themselves rather well to conditions as they existed in the Pacific Theater. In this series approximately 21 per cent were considered as thoraco-abdominal wounds, and 12 per cent developed empyemas. Four cases, or two per cent, required thoracoplasty. A properly-timed open thoracotomy, with decortication, may well have modified or prevented the necessity of these collapsing procedures. Approximately 20 per cent are receiving some pension at this time. All but five per cent have apparently adjusted themselves very well. This would seem to be a rather gratifying figure when one considers the character of injuries sustained.

DISCUSSION.—DR. WILLIAM L. ROGERS, San Francisco, Cal. (closing): I am sorry time would not permit reviewing and discussing the roentgenograms of some of our difficult therapeutic problems and to show their recent follow-up films. We are indebted to Captain Hook, who made it possible for us to see and care for many of these cases while under his command in the South Pacific.

# FRACTURES OF THE OS CALCIS*

## THEIR TREATMENT BY TRI-RADIATE TRACTION AND SUBASTRAGALAR FUSION

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TORONTO, CANADA

FROM THE ORTHOPEDIC AND FRACTURE SERVICE, TORONTO GENERAL HOSPITAL TORONTO, CANADA.

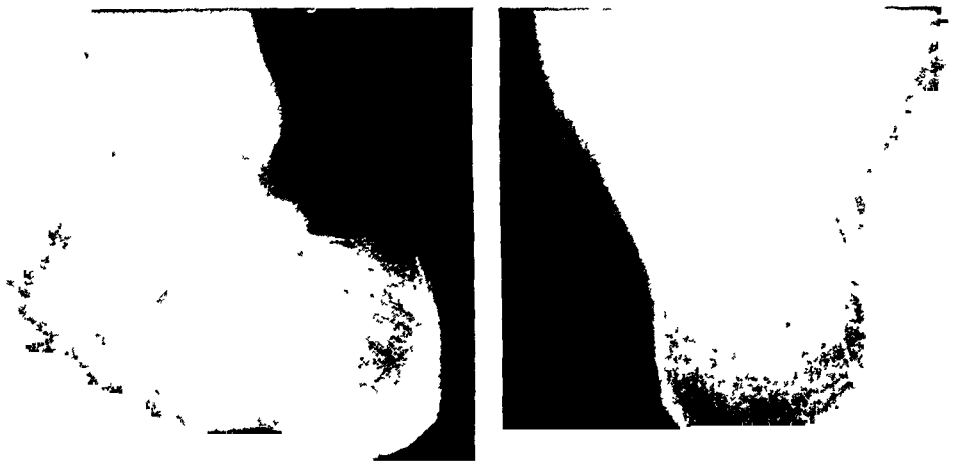
THE MANAGEMENT OF FRACTURES of the os calcis is difficult. There are three reasons for this:

1. Standardization of treatment is nearly impossible because the damage sustained by the os calcis varies within such great limits as to present widely different problems in management. Few fractures are as individualized as are fractures of the os calcis. They range from the most insignificant fissure (Fig. 1) to the most extreme degree of comminution with gross deformity (Fig. 2).
2. The technical problems involved in reduction of the fragments are complex and difficult to solve.
3. Involvement of the subastragalar joint frequently occurs. When it does, late disability from pain on movement is almost inevitable, even though good reduction of the fracture has been obtained.

In so difficult and complex a problem, it is not surprising that much difference of opinion exists regarding the best form of treatment, nor is it surprising that the results often are unsatisfactory.

In civil life most fractures of the os calcis are the result of industrial accidents: Falls from scaffolds, falls from buildings, falls from ladders are the frequent causes of the injury. The records of the Workmen's Compensation Boards bear testimony to the serious disability which is caused by this accident. Dr. D. E. Bell,[1] Chief Medical Officer of the Workmen's Compensation Board of Ontario, has been kind enough to provide me with data relating to 60 consecutive cases of fracture of the os calcis. Simple fractures and much comminuted fractures are included in this group without distinction. The duration of total disability (in almost every case this corresponded to the period from the time of the accident to the time the man returned to work) varied from two and one-half months to 35 months (Fig. 3). The majority of the cases (all save nine) were back at work at the end of 14 months. Most were left with some partial permanent disability necessitating compensation. Thirty-five were placed on pensions varying from 3 per cent to 50 per cent. The remainder received compensation for temporary partial disability at rates ranging from 3 per cent to 35 per cent and for periods ranging from six to 42 months. Not one case reached a finality with no disability at all. Ten cases had subastragalar and midtarsal fusions after rather prolonged periods of disability had demonstrated their inability to work. The average cost was great; $1,350.00 per patient.

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.



A B

FIG. 1.—A fracture of the os calcis with minimal damage to the bone and minimal displacement of the fragments. (A) Lateral view; (B) supero-inferior view. (For contrast with Figure 2.)



FIG. 2.—War fracture of the os calcis, the result of the explosion of a land mine beneath the vehicle on which this soldier was riding. This represents the most extreme degree of fragmentation and deformity which can occur in fractures of the os calcis. Every gradation in severity can occur between that represented in Figure 1, and that represented here.

War now adds its toll to this group of fractures. In the war which has just terminated, severe fractures of the os calcis were amongst the most characteristic of injuries. In civil life the injury is caused by a fall from a height. In war it most characteristically results from force exerted from below. Land mines exploding under vehicles and under tanks drive the floor up against the feet of the occupants with great force. Similarly, when ships are torpedoed or mined, the explosion lifts the deck suddenly and violently. This force is sufficient to cause fractures not only of the os calcis, but often, also, compression fractures of the spine. A war variation of the fractures of the os calcis, which is due to a fall from a height, were those produced when sinking ships developed a list so great that the crew slid across the deck and came up against the bulwark or other object. If their heels bore the brunt of the impact, fractures of the os calcis occurred.

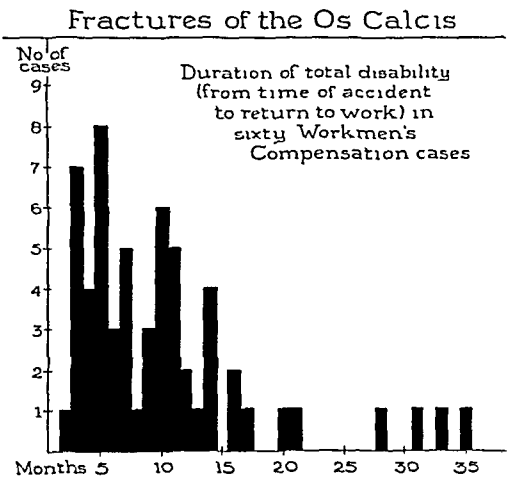



FIG. 3.—Graph of duration of disability in fractures of the os calcis. Workmen's Compensation cases.

War fractures of the os calcis are characterized by an extreme degree of comminution of bone which often is shattered into multiple widely separated fragments (Fig. 2). The injury often is compound. There may be serious injury to the circulation from swelling and vascular damage. For these reasons and also because of transportation problems, there was little opportunity for the early institution of specialized treatment directed towards the reduction of the fragments. Most war fractures of the os calcis have ended with fusion of the fragments into a greatly distorted mass. It must be stated, however, that the degree of permanent disablement, though severe, often is not as great as might be expected from the distortion of the bone.

## BOHLER'S CONTRIBUTION TO TREATMENT

An important landmark in the problem of os calcis fractures has been Böhler's contribution to their treatment. His emphasis upon the multiplicity of fracture types, each of which requires its own treatment, upon the need for the restoration of the bone to its normal shape and the value of traction in securing this, have greatly advanced the standards of our treatment. Perhaps of even greater importance than his contributions to the technic of treatment has been the enormous stimulus he has given to our interest in this grave problem. Nonetheless, the fracture too often is poorly managed.

Many fractures of the os calcis are treated by simple plaster fixation without any attempt at reduction or of restoration of the bone to its normal contour. Commonly, this results from the inexperience of the practitioner

and his inability to handle a complex problem. He puts on a plaster encasement and hopes for the best. But there has also grown up a school of fracture surgeons who advocate "studied neglect" as the best form of treatment. This surely must be a confession of defeat. It is impossible to believe that a badly comminuted fracture of the os calcis with serious involvement of the subastragalar joint will be better if left untreated than if reduced. Even Cotton's method is based upon the principle of reduction of the fragments and restoration of the normal contour of the bone. The initial pounding is for the purpose of disimpacting the fragments so that they may more easily be remoulded into normal relationship.

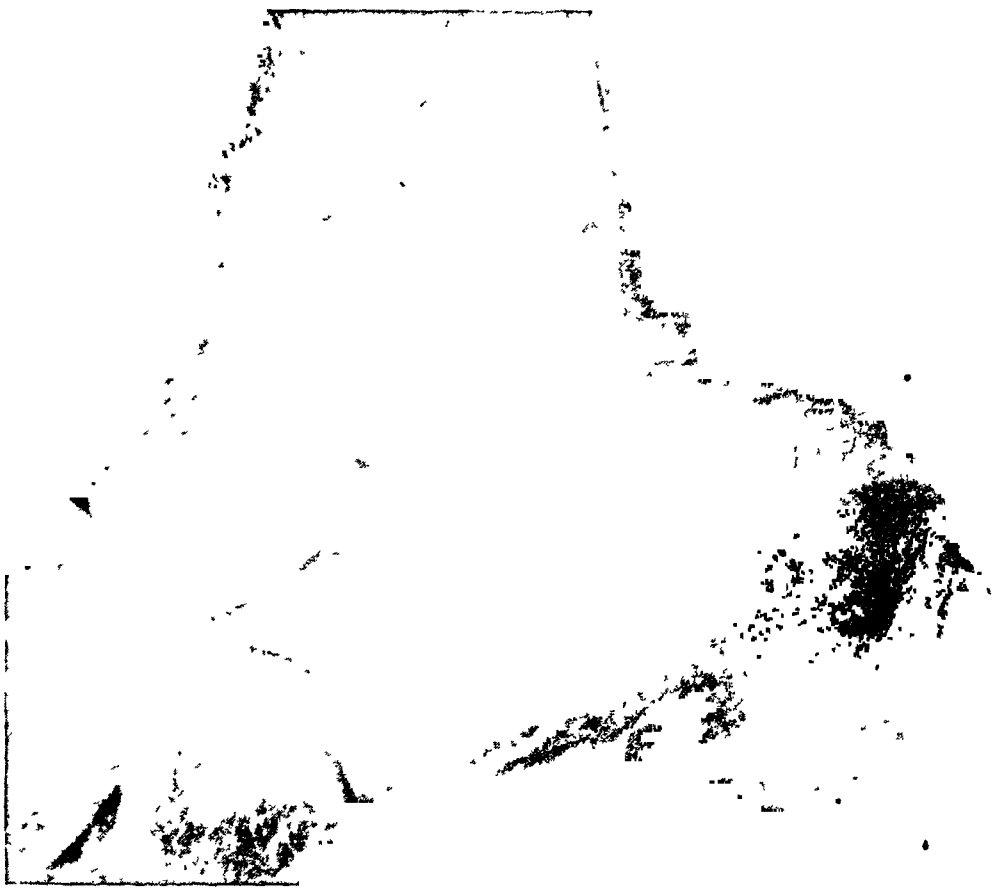


FIG. 4.—Fracture of the os calcis with a central fragment bearing articular cartilage completely separated by fracture lines from the surrounding bone. This results in aseptic necrosis, loss of articular cartilage and damage to the subastragalar joint no matter how perfectly the fragment may be reduced. (See Fig. 13.)

Success in the treatment of this, as of other fractures, is based upon reduction of the fragments to as nearly perfectly normal relationship as possible.

Böhler's plan of treatment, though valuable and important, falls short of perfection on several points. First, and most important, is the assumption that a rigidly formalized procedure will always result in a satisfactory reduction of every fracture of the os calcis. There is so much variation in os calcis fractures, in the amount of comminution and in the degree of displacement, that perfect reduction cannot always be expected from a pro-

cedure which consists of traction in a certain direction with such and such a force followed by traction of a certain amount in another direction. The second defect follows from the first. There is no provision for determining, *during* the period of reduction, whether success has been achieved or not. The stress is upon maintaining a certain degree of traction in a certain direction, the inference being that strict adherence to this formula will be cer-

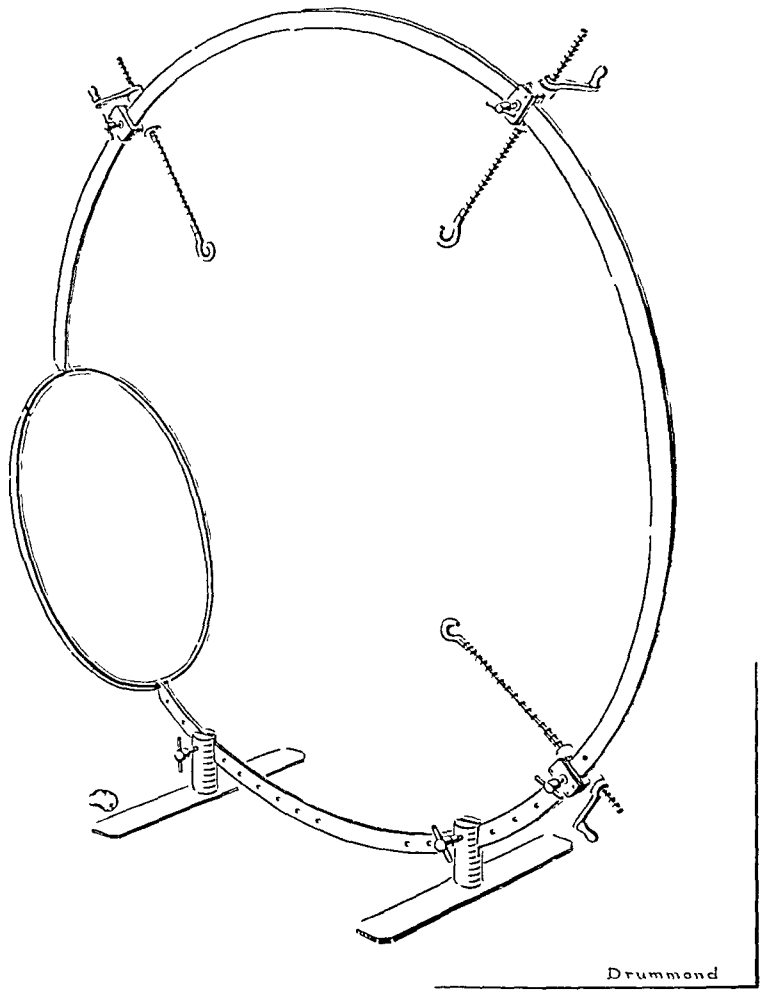



FIG. 5.—Sketch of the traction ring by means of which triradiate traction is used to reduce the fragments of the fractures of the os calcis. The leg is passed through the oval opening. Kirschner wire traction is then applied from three points—shin, heel and toes. The direction of the pull of each traction unit may be altered within wide limits by shifting its anchor-block around the ring. The traction force may be modified by the screw tension.

tain to produce the desired reduction of the fracture. Like most fractures, the success of treatment should be checked by roentgenograms or the fluoroscope. Undue stress, also, is laid on restoration of the critical angle. This is an index that fair restoration of the fragments to their normal relationship has been obtained. Of greater importance is the state of the posterior facet of the subastragalar joint. If this is intact it matters not whether the critical

angle is restored exactly. Good results will follow even when the critical angle is much depressed provided the subastragalar joint is intact. On the other hand, if the joint has been involved in the fracture, the final result is prone to be imperfect no matter how well the critical angle has been restored or how perfect the reduction of the fragments.

Böhler's method of reduction by traction would be improved were there provision for at least one additional point of traction and for greater flexibility in the directions in which the traction can be applied. But even when this improvement has been attained, it is a mistake to assume that the distortion of the bone can be corrected by traction alone. Certain fractures of the os calcis cannot be completely or satisfactorily reduced by traction alone, no matter how skillfully its direction and force may be manipulated. Other means of controlling the position of the fragments often are necessary.

Bohler fails also to lay sufficient stress upon the value of subastragalar fusion in the more serious cases. Disablement from a damaged subastragalar joint is so certain to follow certain types of injury that they should be recognized at the outset and treated by early fusion.

## PRINCIPLES OF TREATMENT OF OS CALCIS FRACTURES

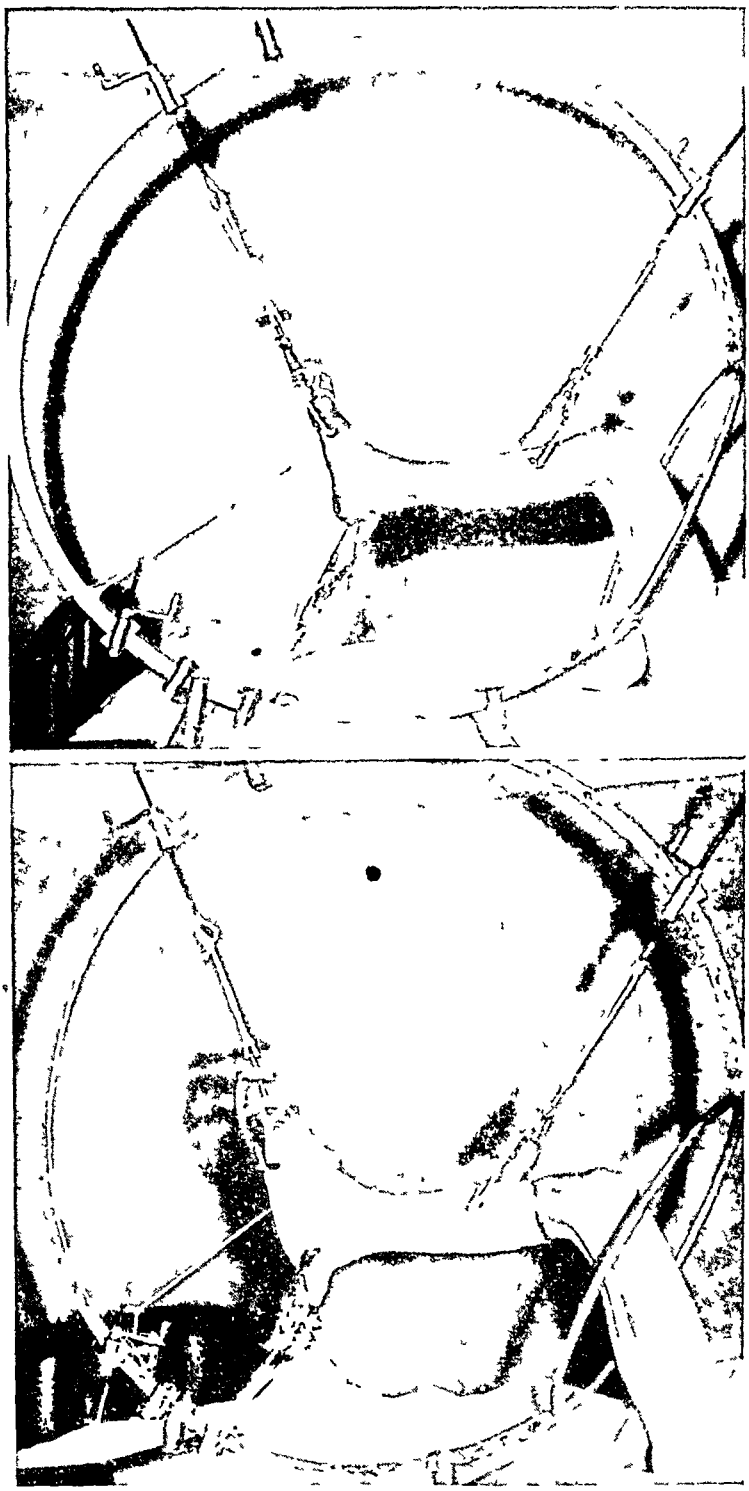
This paper records an attempt to improve upon the treatment of os calcis fractures and relates the results obtained in 35 cases. During the course of this study certain principles of importance have evolved. They form the basis of any rational attempt to improve this treatment of os calcis fractures and are worthy of emphasis.

1. The fundamental principle of treatment is that best results will be obtained by reduction of the fragments to their normal relationship to each other. The more nearly this can be accomplished the better will be the result. Though perfect reduction may not necessarily ensure normal function, it will give the best result obtainable. To leave the fracture unreduced may have the merit of simplicity but it results in too much permanent disablement. "Studied neglect" has no more to recommend it in the treatment of fractures of the os calcis than it has in other fractures.

2. It is important to distinguish between simple and severe fractures of the os calcis. Severe fractures, (*i.e.*, those with much comminution and much displacement) must further be divided into (a) those in which no fracture line traverses the articular surface of the posterior facet of the subastragalar joint, even though the joint be depressed; and (b) those in which the articular surface is fragmented and distorted.

The simple fractures do not present any great difficulty in treatment. If only a simple fissure exists elaborate means to change the position of the fragments are not necessary. Any widening beneath the malleoli may be corrected by lateral compression. When this has been accomplished simple fixation in a plaster encasement is all that is necessary.

If the fracture is severe some or all of the procedures outlined below may be necessary to secure a satisfactory result.



A

B

FIG. 6—The traction ring in use. (A) The fracture has been reduced by tri-radiate traction and the position of the fragments has been demonstrated satisfactory roentgenographically. Note an extra cord holds the forefoot in the midposition between varus and valgus and a Steinmann pin has been used to pry up the anterior end of a major fragment carrying part of the articular facet (B) While traction is maintained, a plaster encasement is applied incorporating the Kirschner wires and the Steinmann pin. (See Fig 7 for roentgenograms.)

3. Skeletal traction is a valuable agent for restoration of the fragments to their normal position and normal relationship to one another. It is important, however, that it be more flexible in its application than suggested by Böhler, and multi-directional. The insertion of the tendo achillis into the os calcis modifies the direction of the force which traction exerts through the wire transfixing the posterosuperior angle of the os calcis. In order that this force may shift the fragment in the right direction and in the right

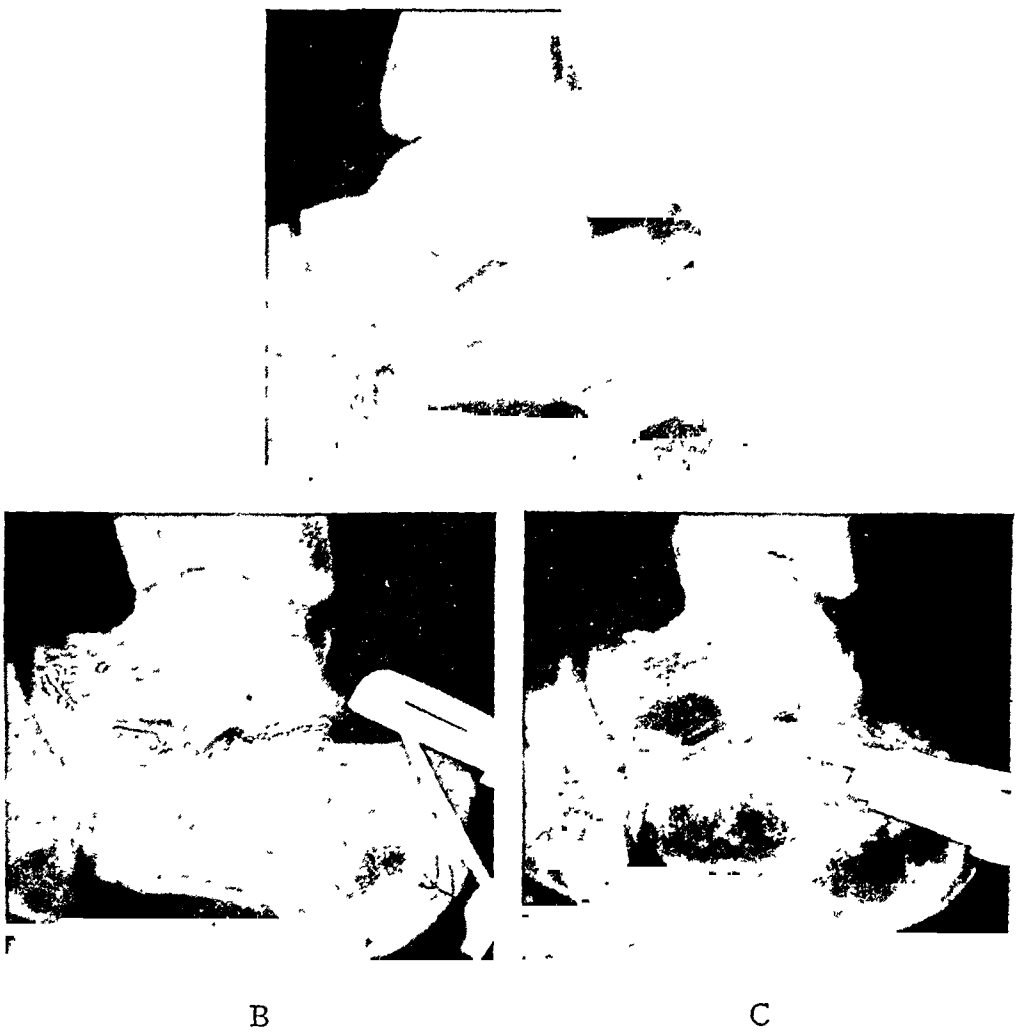



FIG. 7.—Roentgenograms of the patient illustrated in Figure 6. (A) Before reduction. (B) After the application of tri-radiate traction. Position improved but anterior end of a major fragment is still depressed. (C) Restoration of normal relationship by tilting up the depressed fragment with a Steinmann pin.

manner, and to the right degree, controlled means of changing the direction of this pull are necessary. Furthermore, the shortening of the heel often is not satisfactorily overcome by Böhler's traction. Measures to accomplish this by means of a third wire through the heads of the metatarsals is a valuable addition to the traction apparatus.

4. In certain cases, traction is not sufficient to correct all the deformity. Of particular difficulty and importance is the depression of the anterior end

of a major fragment carrying with it part or all of the articular surface of the posterior facet of the os calcis. Sometimes no amount of traction applied in any direction will tilt this up. It can be accomplished by other means. Of particular value is a Steinmann pin hammered into the heel and used as a handle to pry the fragments into the proper position.

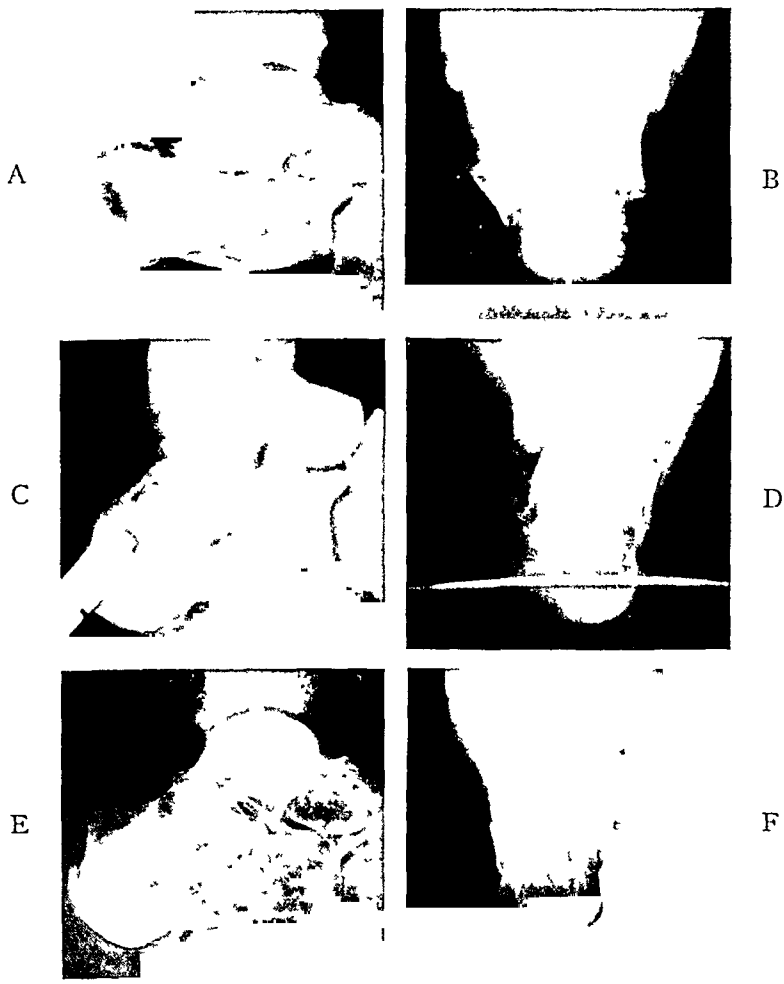



FIG. 8.—Roentgenograms to illustrate the outcome of treatment of tri-radiate traction. (A) and (B) Lateral and supero-inferior roentgenograms before reduction. (C) and (D) Lateral and supero-inferior roentgenograms taken during reduction. In (C) note a large fragment carrying most of the posterior facet of the subastragalar joint completely separated by fracture lines from surrounding bone. (E) and (F) The result three months after reduction. Good union in good position but articular cartilage thin in posterior half of subastragalar joint. (See Fig 9)

5. Reduction must be checked during its progress by roentgenograms or fluoroscopy, and the necessary adjustments made to achieve the perfection of reduction which is desired. This is important. It is impossible to know what has been accomplished by attempts at reduction except by roentgenograms. So often is the first attempt at reduction imperfect that check roent-

genograms at the time are the only reasonable means of obtaining good results. In this respect, fractures of the os calcis do not differ from other fractures.

6. The widening of the heel which results from the bursting force of the injury must be accurately and completely reduced. This is best accomplished by skillful moulding rather than by great compression force. When the fragments of the bone have been restored to length by traction it does not require great force to reduce the excessive width. The attempt to accomplish this by powerful compression leads to the use of instruments which make nice adjustments difficult and uncertain.

7. If there has been fragmentation of the articular surface of the posterior facet of the calcaneus, permanent disablement from painful limitation of movement of the subastragalar joint is virtually certain to occur. No means of reduction which we possess can so exactly replace the fragments that perfect restoration of the normal contour can always be attained. Therefore, involvement of the joint surface by fracture lines predicates the likelihood of late disability which can only be relieved by fusion.

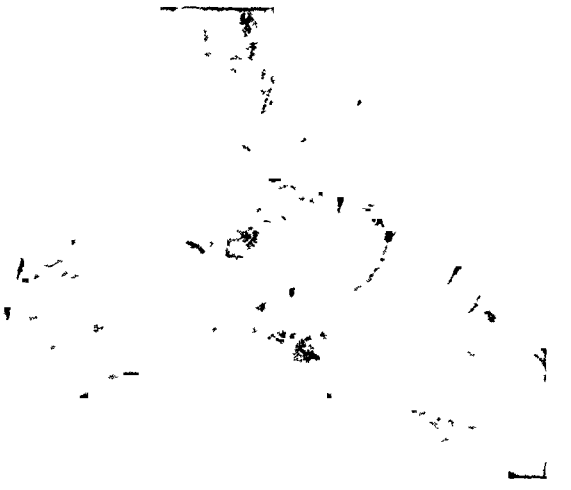


FIG. 9.—The final result obtained in the case illustrated in Figure 8, two years after reduction. Loss of cartilage in the posterior facet of the subastragalar joint, sclerosis of the bone and osteo-arthritic lipping of the posterior margin of the joint. The case illustrates well the complexity of the factors involved in the achievement of a good result in the treatment of fracture of the os calcis. The fracture was much comminuted and there was much displacement. Nevertheless, excellent reposition of the fragments was accomplished. The late result was imperfect because aseptic necrosis of a central fragment caused loss of articular cartilage and traumatic osteo-arthritis. The joint was limited in movement and painful. Subastragalar fusion would have improved the result.

8. Even though it were possible to secure perfect reduction of the fragments involving the joint surface, we must still recognize the frequent occurrence of *aseptic necrosis* of fragments cut off from their blood supply by the fracture lines (Fig. 4). In due course, they undergo changes which result in loss of articular cartilage and deterioration of the joint.

9. These two factors (fractures through the joint surface and the occurrence of aseptic necrosis in one or more of the fragments) lead, with certainty, to permanent disability. Such cases should be treated by subastragalar fusion to obtain the best result. They should, therefore, be recognized at the beginning and fused as early as possible in order to reduce to a minimum the time for treatment. In most cases it is not necessary to fuse the midtarsal joint.

10. The importance of accurate reduction of the fracture is so great that the accomplishment of it by open operation naturally arises as a possibility. Our experience with this procedure is not entirely satisfactory. No

incision adequately exposes all the fragments of the fracture. Any attempt at restoration of the fragments is nearly impossible because the crushing of the cancellous center of the bone reduces a large part of the bone to mush. Fixation after reduction is difficult or impossible. Open reduction, therefore, is far from ideal. Nevertheless, two fresh fractures treated by immediate open operation and immediate subastragalar fusion are among the most satisfactory cases we have had. They returned to work in four months, with painless feet. This is a tribute to the value of early fusion rather than open operation since the deformity of the bone was poorly corrected.

### A PLAN FOR THE TREATMENT OF THE OS CALCIS FRACTURES

The plan of treatment which this paper records consists of the following steps:

The injured foot and the roentgenograms are examined to determine whether or not the fracture is of such severity as to need reduction. The simple fissure types (Fig. 1) are treated by fixation in a plaster encasement only.

The severe types of fracture are reduced under anesthesia using a traction ring of our own design (Figs. 5, 6, 7). This device permits us to use three points of traction and to shift the direction of each within a considerable range (tri-radiate traction). The force of the traction is also capable of easy adjustment by screws.

To reduce the fracture, Kirschner wires are first passed (a) through the upper end of the crest of the tibia; (b) through the posterosuperior angle of the os calcis; and (c) through the distal ends of the fifth and first metatarsals. Care must be taken in the placing of these wires, that they be parallel to one another when the foot is in the position of reduction. The wire B., moreover, must be very exactly placed in the extreme posterosuperior corner of the os calcis in order that maximum control over the fragment may be secured.

When spreaders have been attached to the wires they are, in turn, secured to the tractors by short lengths of fine sash cord. Tri-radiate traction is then applied in the directions which seem most likely to reduce the fracture. The result is checked by roentgenograms taken in the operating room. If the reduction is not satisfactory, adjustments of the direction and tension of the traction are made and the result again checked roentgenologically. These adjustments are continued until the best possible result is secured. As a rule, this proves to be a simple procedure. The first attempt often is satisfactory.

If there is a major fragment carrying articular cartilage, the anterior end of which remains depressed in spite of every effort of traction (Fig. 7), it is elevated by the use of a Steinmann pin. This is securely driven into the fragment from behind and is then used as a handle by means of which the fragment is tilted into place. The projecting end of the pin is tied in the proper position to the Kirschner wire-spreader.

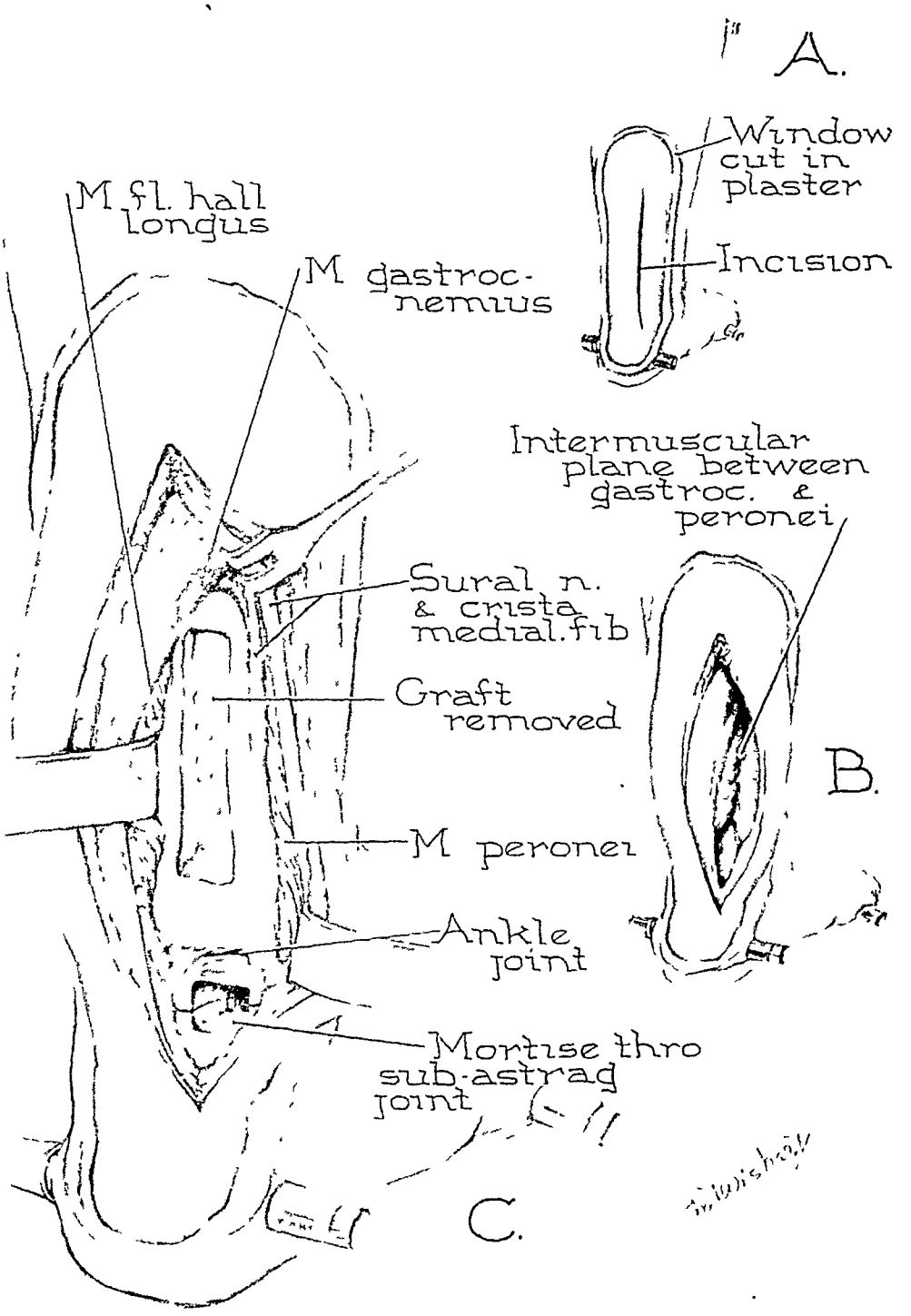



FIG. 10.—Gallie's operation (slightly modified) for fusion of the subastragalar joint through a posterior approach.

First Stages: (A) The incision lateral to the tendo achillis made through a large window in the encasement. The transfixing pins still in place and incorporated in the encasement. (B) The approach to the posterior surface of the tibia and the posterior end of the subastragalar joint by opening the intermuscular plane between gastrocnemius and peronei. (C) Flexor hallucis longus detached from its fibular origin and retracted medially with the tendo achillis. Rectangular mortise cut in subastragalar joint. Graft removed from posterior surface of tibia with osteotome.

When the lateral roentgenogram shows satisfactory restoration of the position of the fragments, the widening of the os calcis is reduced by moulding pressure from either side. This does not require great force. We prefer not to use Bohler's crushing clamp because it is needlessly powerful and is clumsy to use. Often the moulding can be accomplished by the hands alone. The final position of the fragments is determined by a supero-inferior roentgenogram (Fig. 8).

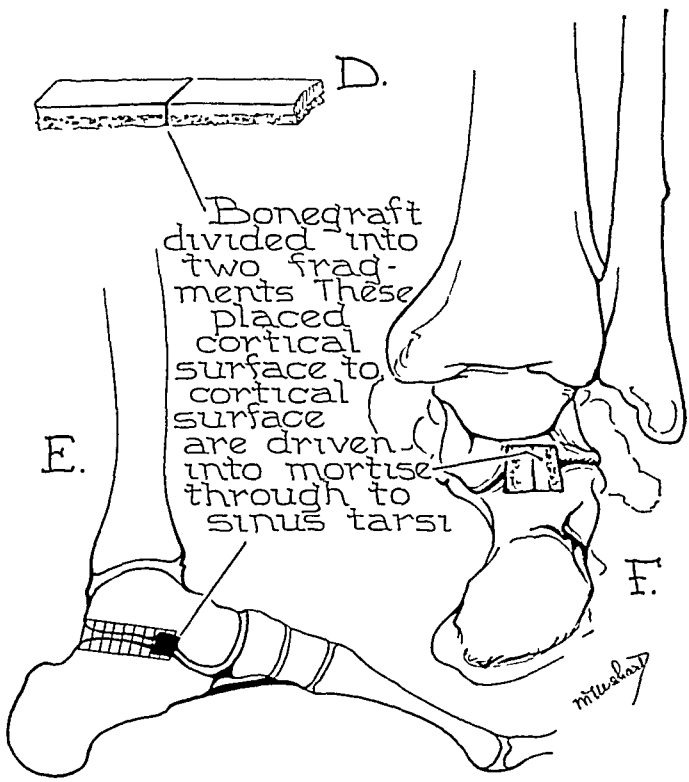



FIG. 11.—Gallie's operation for subastragalar fusion through a posterior approach.
Final Stages: (D) The bone graft is divided into two equal fragments. (E) and (F) The grafts are driven into the mortise in the subastragalar joint.

With traction still on (and the Steinmann pin still in place if it has been used) a plaster encasement is applied from toes to top of calf, incorporating the wires and pin in the encasement. The patient is then returned to the ward still suspended in the traction ring. It is removed 48 hours later, when the plaster is completely dry.

From a study of the postreduction films, a decision is reached upon the necessity, or otherwise, for subastragalar fusion. The criterion for this decision is the degree of fragmentation and deformity of the articular surface, of the posterior facet of the os calcis. If this is seriously involved, or if there are loose fragments likely to undergo aseptic necrosis, fusion will be

necessary to secure the best result even though there has been good reduction of the fragments.

The importance of fusion of the subastragalar joint in selected cases should be emphasized. It has been our experience that many fractures of

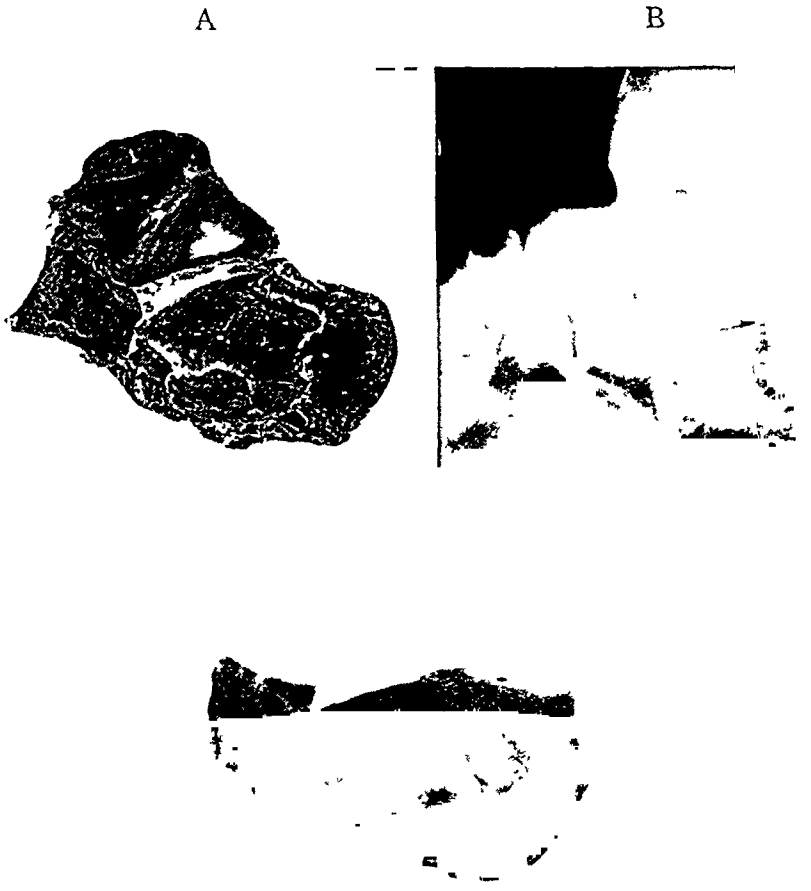



FIG. 12.—A postmortem specimen of fracture of the os calcis. Death occurred five days after the accident.

(A) Superior oblique view of the fractured bone illustrating the great comminution of the bone and distortion of the fragments. The fragments are firmly impacted into each other and have resisted preparation of the specimen without falling apart. (1) Sustentaculum tali; (2) anterior portion of the articular facet; and (3) posterolateral portion of facet driven down into the body of the os calcis.

(B) Roentgenogram of the fracture on admission of the patient.

(C) Roentgenogram of the specimen from a somewhat different angle than the clinical roentgenogram. This rare specimen illustrates well the great complexity of the fracture, the multiple fracture lines, the great displacement of the articular surface and the impaction of the fragments. It makes clear many difficulties which beset the treatment of this fracture.

the os calcis, even though well reduced, are seriously disabled by painful limitation of movement of the subastragalar joint because of involvement of the articular surface of the os calcis. When the painful joint is adequately fused the improvement is great and more than compensates for the loss of

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movement in this joint. The development of a simple and effective technic for subastragalar fusion by W. E. Gallie[2] leads us to feel that it should be used in all cases in which there is any appreciable damage to the subastragalar joint.

If subastragalar fusion is advisable it should be performed early to avoid needless prolongation of treatment. The common procedure is to reduce the fracture, maintain fixation till union is complete, and return the man to work after a period of rehabilitation. About six months after the fracture, it begins to be apparent that he is handicapped by painful limitation of movement at the subastragalar joint. Sometime later the subastragalar joint is fused to cure his pain. This operation requires another six months of fixation

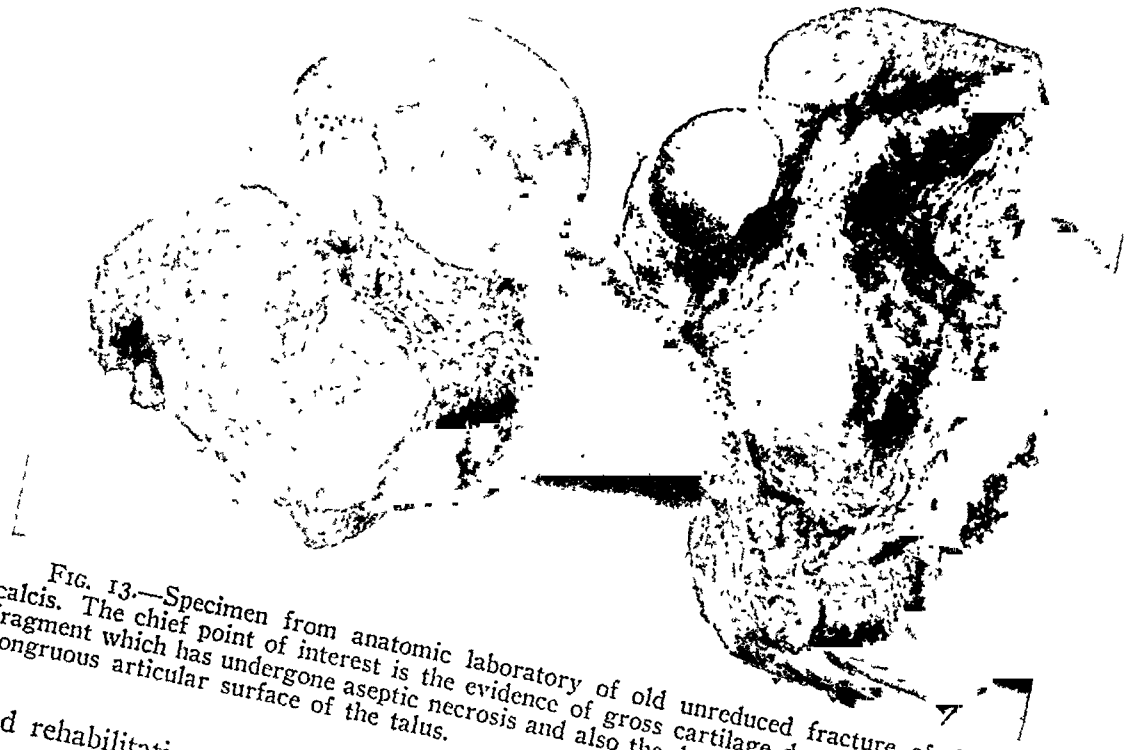


FIG. 13.—Specimen from anatomic laboratory of old unreduced fracture of the os calcis. The chief point of interest is the evidence of gross cartilage damage on a central fragment which has undergone aseptic necrosis and also the damage this has caused to the congruous articular surface of the talus.

and rehabilitation before he can resume work. Our great objection of subastragalar fusion has been the great loss of time it involves. If it is performed early this objection is eliminated. To do so necessitates deliberate selection of cases for fusion at the beginning of treatment of the fracture.

Cases which are judged suitable for subastragalar fusion are operated upon ten days after the primary reduction. The joint is fused from behind, after the method of Gallie,[2] through a large window cut in the plaster encasement over the tendo achillis. The transfixing wires remain incorporated in the encasement and are not disturbed. Gallie's simple procedure can be recommended as highly suitable for the problem of the fractured os calcis.

The only important precaution is to be certain that no varus deformity exists. Fusion of the subastragalar joint in varus causes disability from uneven weight distribution on the forefoot.

The operation (Figs. 10 and 11) exposes the subastragalar joint from behind by an incision lateral to the tendo achilles. The intermuscular plane between the gastrocnemius and the peroneii is entered and the fibers of the flexor hallucis longus detached from the fibula. With the tendo achillis they are retracted medially. This exposes the posterior surface of the lower end of the tibia, the posterior capsule of the ankle joint and the posterior end of the subastragalar joint. A rectangular mortise is cut in the subastragalar joint with a suitable osteotome, care being taken to ensure that it opens the astragalus and the os calcis equally. The mortise is continued forward to the sinus tarsi. A graft of suitable width is then removed from the lower end of the posterior surface of the tibia. For this purpose an osteotome must be used since the depth of the wound precludes the use of a motor saw. This modification of Gallie's original procedure is necessary because the shin is enclosed in plaster. The crest of the ilium would serve equally well. When secured, the graft is cut into two pieces and driven into the mortise. The wound is then closed, the window in the plaster filled in with a large dressing and secured with an encircling plaster.

The plaster with its transfixing traction wires remains in place eight weeks. If fusion has been performed it is replaced by a walking plaster. Otherwise, the patient begins at once to walk.

The policy of early subastragalar fusion saves months of time and permits severe cases to return to work almost as soon as the simpler cases.

### RESULTS OF TREATMENT

Since June, 1938, 35 patients with 47 os calcis fractures have been treated by this method. The results are satisfactory and are an improvement upon our previous results. Tri-radiate traction with roentgenographic control has proven a much more efficient means of securing reduction of the fragments than is Böhler's procedure. The addition of leverage with a Steinmann pin still further improves the reduction in difficult cases. Early subastragalar fusion of those cases in which there is much comminution of the posterior facet of the os calcis eliminates quickly what would otherwise be a prolonged, probably a permanent disability. The midtarsal joint does not need to be fused. Gallie's posterior approach to the subastragalar joint and his method of fusion are ideally adapted for this purpose. They permit an easy and quick exposure of the joint. The graft can be taken from the posterior surface of the tibia through the same incision. The operation can easily be performed through a window in the plaster.

With one exception all the cases were back at work within six months, some in much less time than six months. The most impressive results were obtained in those cases in whom the subastragalar joint had been fused. The contrast between the extreme degree of comminution seen in the original

roentgenograms, and the painless useful foot obtained by reduction and fusion was dramatic. One case illustrated this well since his bilateral fractures were treated, one without fusion because the fracture did not greatly disturb the joint and good reduction was obtained; the other by early fusion because

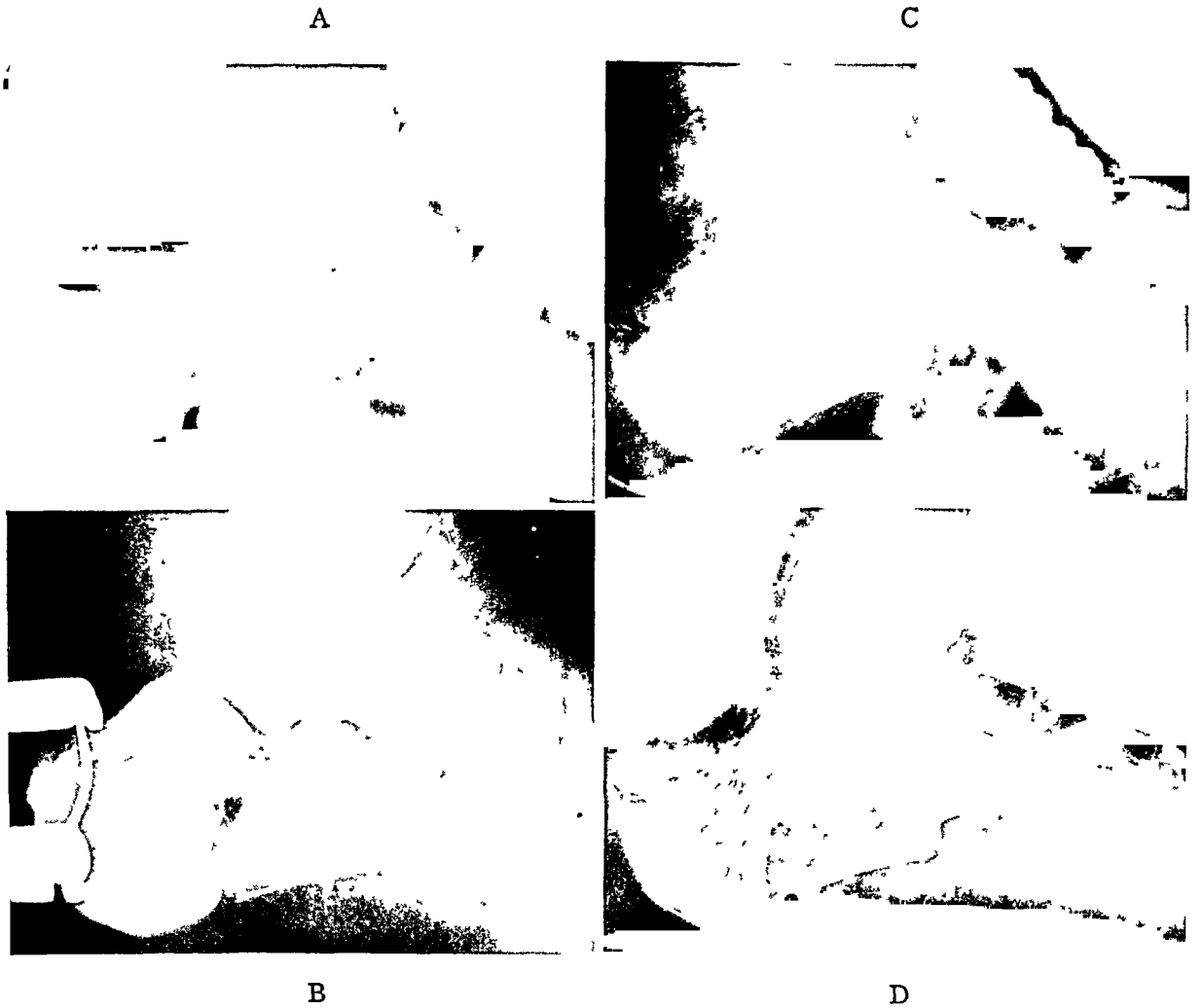



FIG 14.—Series of roentgenograms to illustrate treatment of severe fracture of the os calcis by tri-radiate traction and early subastragalar fusion. (A) Roentgenogram before reduction. Severe fracture with much comminution, displacement and involvement of articular facet. (B) Reduction obtained by tri-radiate traction. Improvement in position but great involvement of subastragalar joint makes impaired function a certainty. (C) Early subastragalar fusion by posterior approach through a window in the plaster encasement. (D) The final result, which gave a stable and painless foot, six months after fusion

of the extensive involvement of the joint. The foot upon which the fusion has been performed proved much the better foot, completely painless and stable.

The single exception to these good results was the result of complications which must be put on record. A low-grade but extremely persistent infection with *B. proteus* developed late (12 weeks) in the transfixion wound which carried the wire for the posterior superior corner of the os calcis.

It cleared after many months. Later, a spur on the plantar surface of the os calcis made walking painful and had to be removed. Finally, his return to active work was prevented by a mild hemiplegia due to cerebral thrombosis. The final result has been good in spite of the hemiplegia, though it has taken many months to achieve it.

SUMMARY

1. Fractures of the os calcis often present difficult problems in treatment and give rise to late disablement of considerable severity.
2. A plan for the improved treatment of fractures of the os calcis is outlined. Its important features are (1) an improved method of securing reduction of the fracture by means of tri-radiate traction supplemented by leverage with a Steinmann pin in certain cases; (2) the necessity of early subastragalar fusion in every case in which the posterior facet of the os calcis has been involved; and (3) Gallie's method of subastragalar fusion by a posterior approach is advocated.
3. The result obtained by such treatment on 35 patients is recorded.

REFERENCES

[1] Bell, D. E.: Personal communication.
[2] Gallie, W. E.: Subastragalar Arthrodesis in Fractures of the Os Calcis. Jour. of Bone & Joint Surg., 25, 731–736, October, 1943.

DISCUSSION.—DR. KELLOGG SPEED, Chicago, Ill.: I agree with nearly every point in Doctor Harris' thoughtful paper, and might add that these fractures are the most frequently found simultaneously bilateral in the extremities. In some instances it is impossible with bi- or tri-radiate traction complemented by lateral compression to effect a satisfactory reduction after compression fracture of the calcaneus. The earlier the attempt after fracture the better the reduction may be. Application of lateral compression, when indicated by the broadening mushroom flattening of the comminuted bone, should be performed after the skeletal or extra-osseous traction on the heel is in place. When the fragments of bone are so small that a wire may not be used without additional splitting or displacement of fragments, I prefer to use pin-traction immediately posterior to the surface of the bone in front of the attachment of the tendo achillis. This can be inserted by hand through a small puncture incision and does not traverse the bone, although it may enter the hematoma about the fracture.

A postreduction roentgenogram will never tell all the success or failure of the restored position of the fragments. Inequalities must exist in every instance when the subastragalar joint is involved, but they may be healed over fibrously and aided by long freedom from weight-bearing, after which the underlying cancellous bone may eventually support body weight without pain. When there is gross inequality of the superior articular surface of the calcaneus, pain is inevitable for most individuals unless a natural bony arthrodesis develops. If the freedom from weight-bearing is persisted in only long enough to permit surface healing of the cartilage defect by fibrous tissue, the underlying cancellous bone will not have sufficient strength to support this surface when weight-bearing is attempted, and there will ensue a secondary collapse with increasing deformity of the articular surface and increasing pain. This I believe is even more important than the factors of aseptic necrosis of bone fragments and the so-called joint deterioration described by Doctor Harris. We must not conceive

the bone as having a center of cancellous bone; it is completely cancellous, with a cortex almost as thin as paper.

If Doctor Harris' ingenious traction ring is not available a variation in traction may be accomplished by using the modern fracture table, knee flexed and suspended with skeletal traction on heel and foot adequately applied to the metal foot piece. But this cannot remain there for 48 hours, thus failing to achieve the efficiency of the traction ring.

We must agree that arthrodesis is the best method of treatment for the severe fracture. After trial I believe Gallie's method is an excellent one. The posterior approach with the foot stabilized in plaster or traction permits a thorough yet dainty use of the chisel to freshen the articular surfaces, and avoids the long and disadvantageous lateral incision which may not heal cleanly or rapidly. Lateral approach, however extensive the incision, also does not permit full exposure of the superior surface of the calcaneus and cannot be used so soon after the fracture as the Gallie method. Valuable time is thus lost in the healing of the lesions as a whole, including atrophy of the leg muscles. One difficulty in the technic of the Gallie operation is in getting the fusion far enough anterior to promote firm supporting bony union.

DR. GEORGE BENNETT, Baltimore, Md.: I really did not intend to discuss this paper because I do not think there is anything left to be said. Doctor Harris covered briefly and concisely the fundamental points that must be considered in treatment of fractures of the os calcis. I am in complete agreement with his views. I think meticulous study and care of these cases with these principles carried out will eliminate a great deal of disability.

DR. R. I. HARRIS, Toronto, Ont. (closing): I should like to state that the paper is based upon the treatment of 35 patients who had 47 fractures of the os calcis. The results are satisfactory, and are an important improvement over our previous results. With one exception all were back at work in six months or less. The most impressive results were in those on whom subastragalar fusion had been done. These were the worst cases, severely comminuted and with involvement of the subastragalar joint; yet it was possible to get them back to work early (six months) with a painless foot.

# COMPOSITE FREE GRAFTS OF TWO SURFACES OF SKIN AND CARTILAGE FROM THE EAR*

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AND

Lt. Col. Bradford Cannon, M.C., A.U.S.
Boston, Massachusetts

This type of free graft from the ear, consisting of two surfaces of skin and intervening cartilage, was reported from this Service, first in Surgery, Gynecology, and Obstetrics, March, 1946, Vol. 82, 253–255. Further observations have been made and are recorded here along with material from the original publication.

The procedure is still recognized as a difficult one whose success is dependent on a rather small margin of obtaining a satisfactory minute blood supply for a relatively small piece of grafted tissue. The usefulness of the graft is found mainly in reconstruction of the nasal tip, columella, and ala, and as most defects here have scarred edges, the problem of dissecting back to the adequate minute blood supply in this donor site must be met.

The grafts make possible the transfer of a bulk of tissue with two surfaces of skin and an upright or armature of cartilage between them, and are obtained from any part of the ear where this condition exists. The helix and the crus of the helix are used mainly, and other areas around the triangular space and some flat grafts with one surface of skin and attached cartilage are possible. These are taken from these same areas or from behind. The contained cartilage gives the desired form and stability to the graft, and, at the same time, this same cartilage apparently makes the grafting of this bulk of tissue possible by supplying an internal stretch of the skin and support while the blood supply is being established around the edges. This transplanted cartilage does persist and can be definitely felt in the graft months after transplantation.

The donor site in the ear is repaired directly with a local flap or closure, or directly with a scalp flap, the open ear being planted under the flap. This flap is let loose later and a free skin graft used on the scalp if necessary. This procedure on the ear is outlined in Figures 1 and 2. Little deformity

*This work has been done in association with Major Carl Lischer, Major William Bowdoin Davis, Captain Andrew M. Moore, Captain Joseph Murray, Lt. Allyn McDowell, Lt. Milton Edgerton, Lt. Paul Jensen, Major Byron West, Major R. W. Shearburn, Major Parke Scarborrough, Major Sidney Bloom, and other surgeons working in this Plastic Surgery Center, at Valley Forge General Hospital.

Read by Title at the American Surgical Association Meeting, April 2–4, 1946, Hot Springs, Virginia.

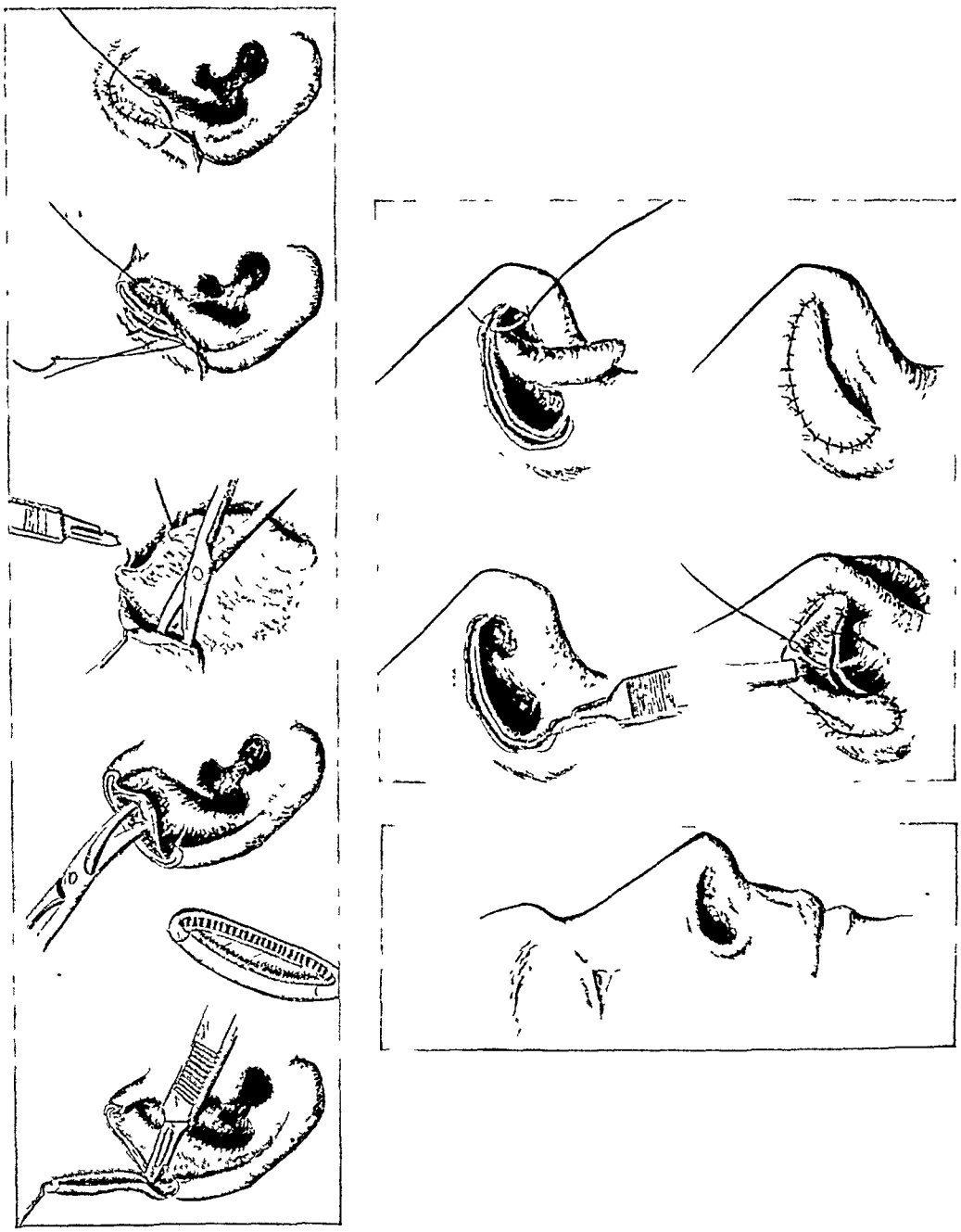


FIG. 1.—Composite free graft from ear to reconstruct nostril border. Single operation on nose.

results, and the patients do not complain. If the ears are burned, or otherwise destroyed, the source of graft is lost, but it was a damaged ear that

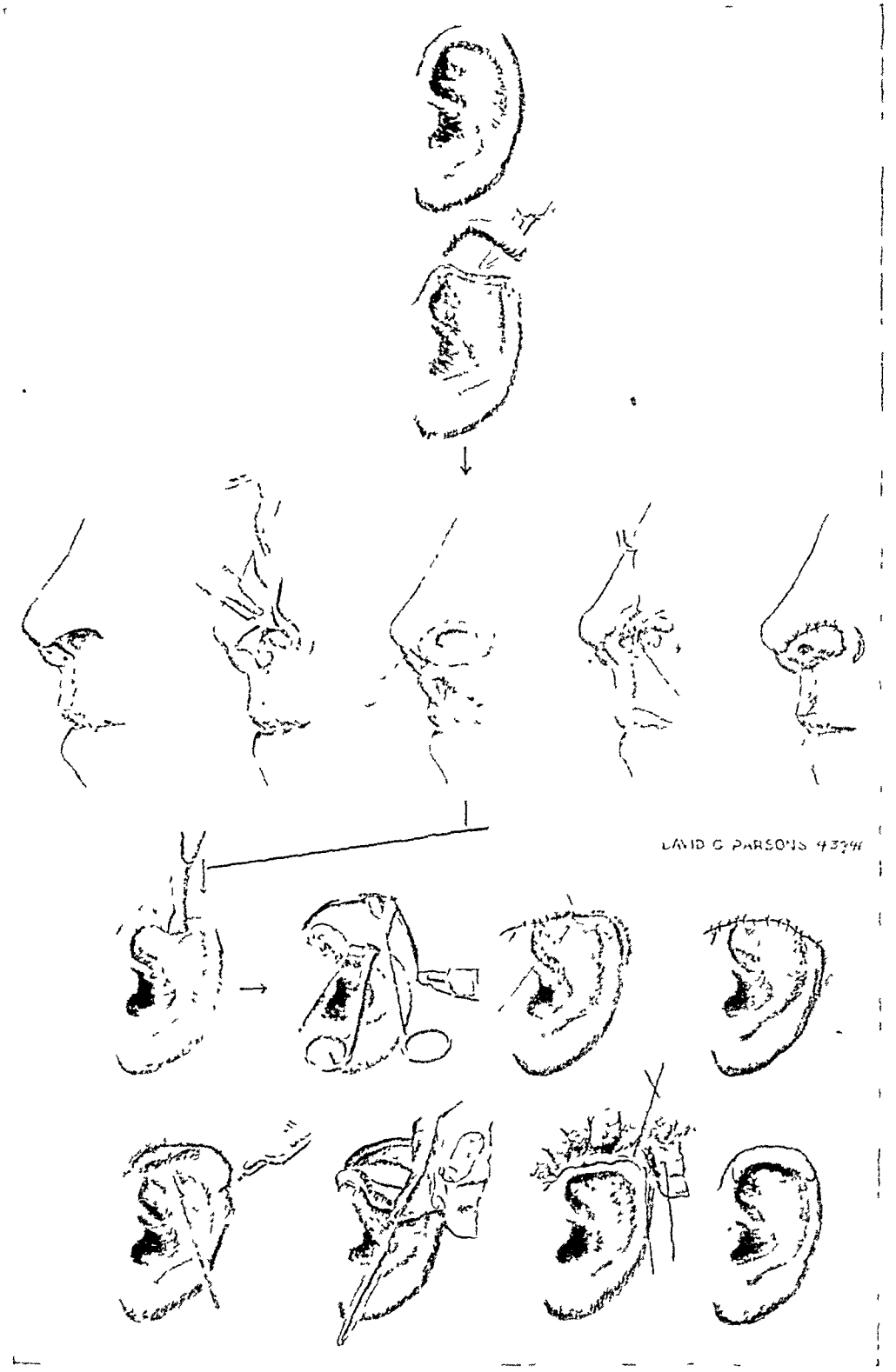



FIG. 2.—Reconstruction of ala, angle and columella with a single composite free graft in one single operation. Secondary freeing of the ear from the scalp flap. Patient shown in Figure 3.

the first one of these grafts was taken from, and Figure 4 shows the use of a burned ear.

Losses about the tip of the nose and the ala and the columella are the ones for which this graft is best adapted. While such a small loss as an ala, or a columella, or the tip of a nose may seem trivial to many (and perhaps especially to most members of this association), to the patient the defect is a serious one. This type of repair, done in a single operation,

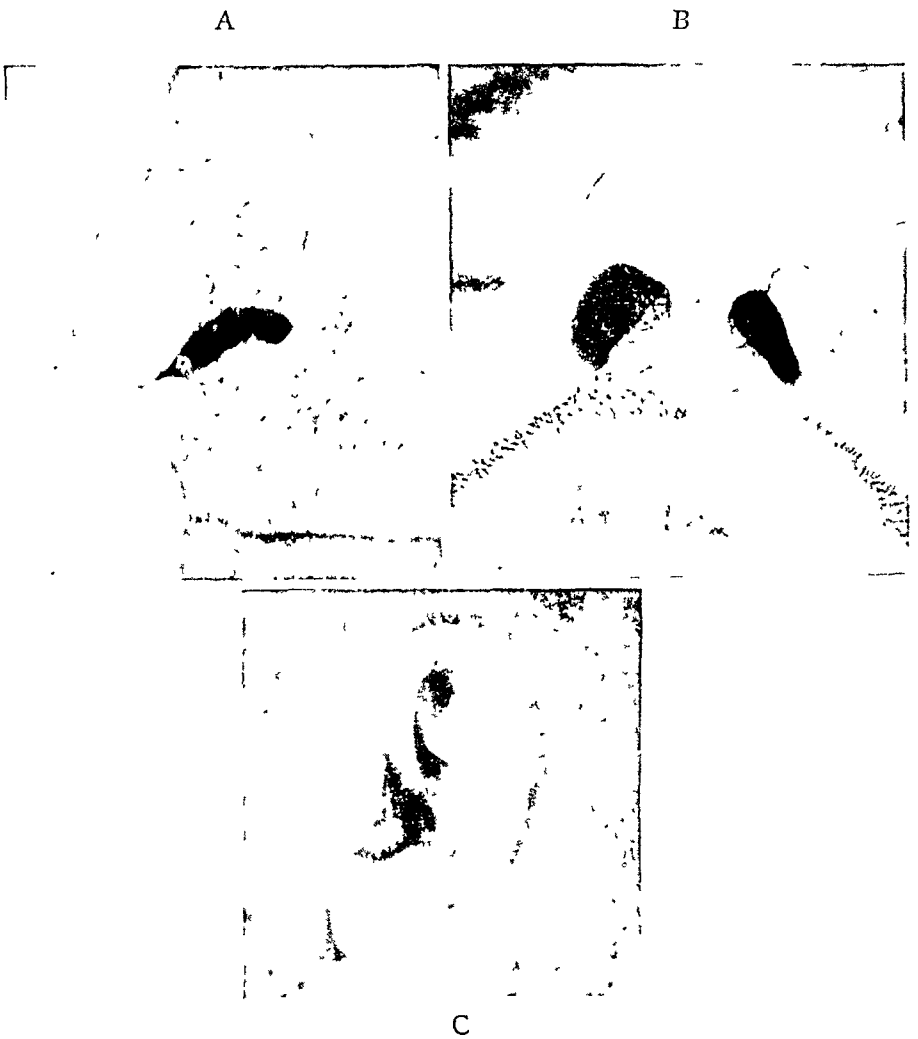



FIG. 3.—Restoration of ala, angle, and columella in one operation, with a free composite graft from the ear. The ear is shown after the scalp flap has been loosened.

usually gives the best restoration and avoids the use of distant (or local) flaps with multiple operations and further scarring. Simple alar losses that can be repaired with rotation flaps from along the nasolabial fold are, of course, still done in this manner, and no dogmatic statements are intended as to the use of this procedure. It is simply recorded as a worth while possibility—labor-saving and rapid, and as possibly giving the most satisfactory results in many instances.

Since the original publication the use of the composite graft has been extended, larger grafts have been used (Fig. 6), triangular pieces have been

successfully set-in to enlarge generally contracted nostrils, more columellae have been added to or restored, and more double alar transplants have been done—*i. e.*, on both alae (Fig. 4). Defects of the whole ala around the tip and clear down the columella have been repaired in single operations with single composite grafts, as shown in Figures 2 and 3. In total burns of the nose it has been possible to resurface the whole nose with a free skin graft

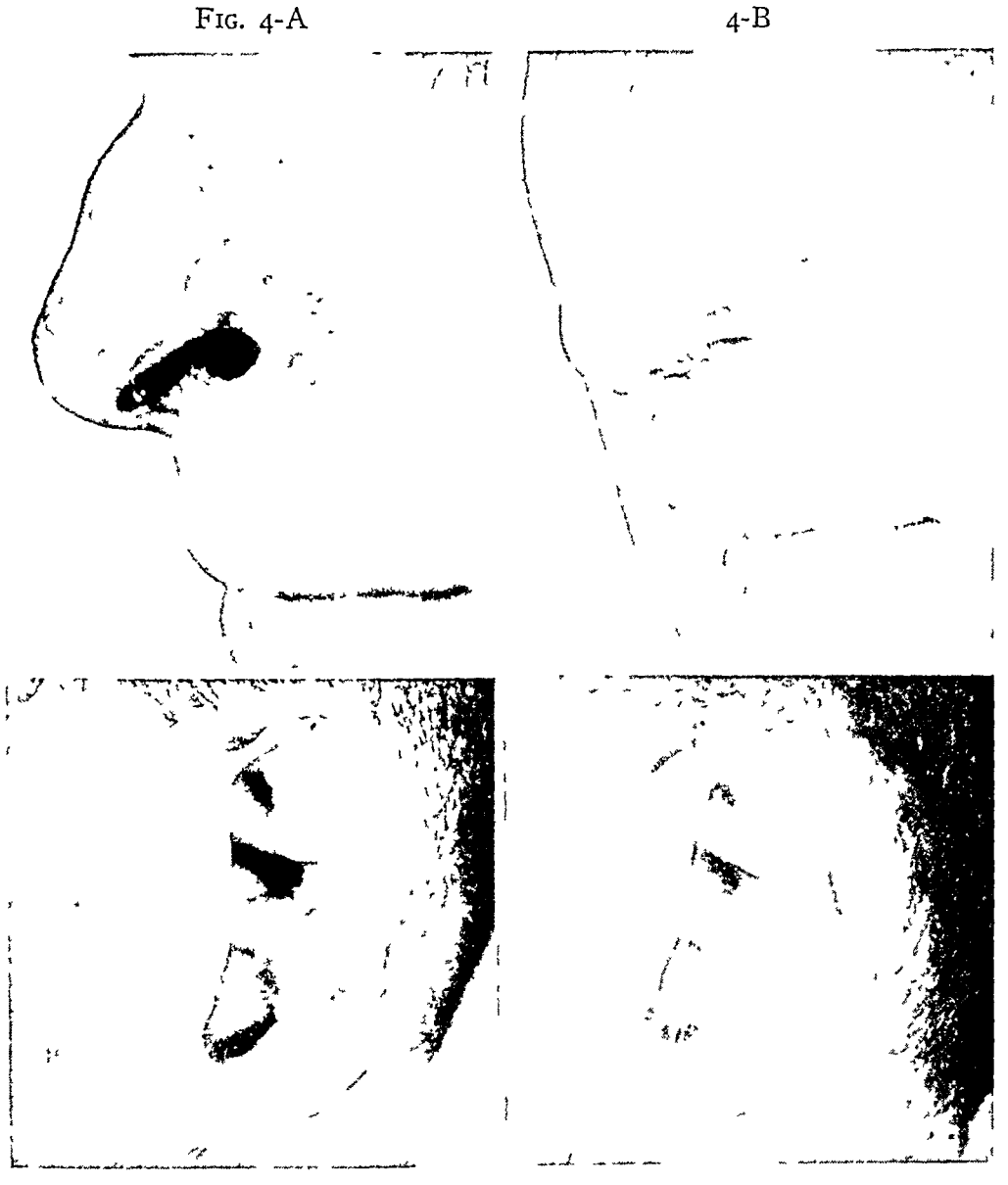



FIG. 4.—Total resurfacing of burned nose in single operation with a full-thickness graft from above the clavicle. Reconstruction of both alae later with free composite grafts from the ear at one operation.

Burned ear used for alar reconstruction and repair of ear after removal of graft.

and then put on ala with these grafts, thus, avoiding large distant flap restoration (Fig. 4). Also, of importance is the repair of small notches that formerly were collapsed and sutured or had flaps rotated down into place with additional scars. The tiny grafts used in these instances are trying of patience, but are worth while.

Small flat defects at the tip and flat losses of the columella have been repaired with flat grafts with one surface of skin and underlying cartilage (Fig. 5). These are most questionable of survival of all types and so far have been used of only small size. To provide columella there must be a septum left high up that can be opened for blood supply.

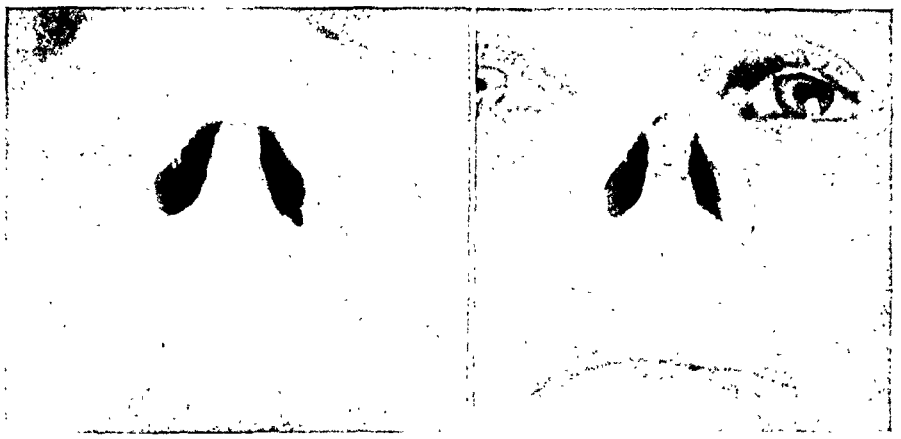


FIG. 5-A FIG. 5-B

FIG. 5.—Restoration of columella in single operation with free composite graft from ear.

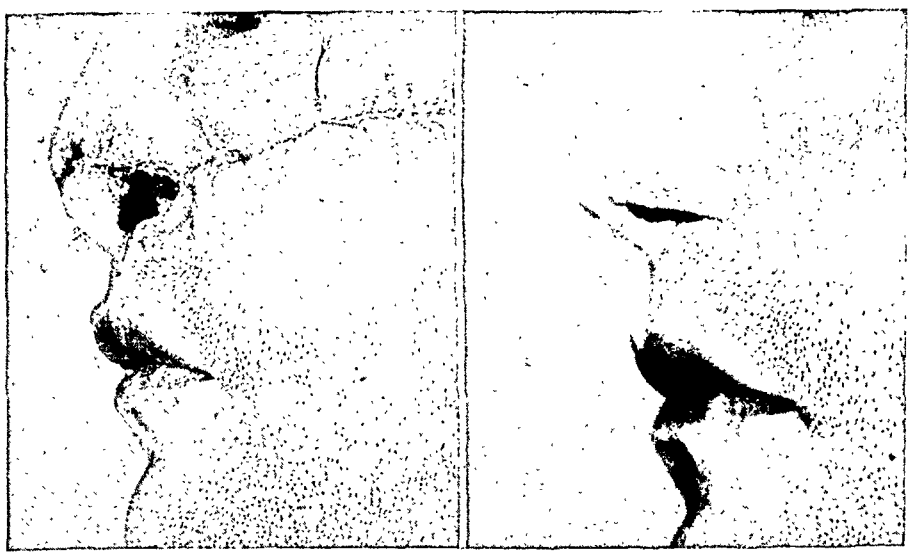


FIG. 6-A FIG. 6-B

FIG. 6.—Large nasal restoration in single operation with large composite free graft from ear.

At operation, the defect is opened carefully, the edge scar discarded, and a good minute blood supply is opened into. This increases the size of the defect and if the contracted tissues need opening they are dissected back into place. An accurate pattern is taken with celluloid.

The pattern is marked out on the ear and the graft removed by careful through-and-through incisions, and especial care is taken not to dislodge the

skin from the cartilage, or to slide it off. The cartilage must be maintained as a composite part of the graft and not dislodged or loosened in its bed.

The graft is sewed accurately into place with fine white silk sutures at each end of the cartilage and then with fine interrupted silk sutures all around the edges, inside and out. The area is carefully packed and a firm pressure dressing applied, usually using an aluminum splint over soft pads.

The course of the graft is apt to be somewhat distracting with blueness and redness and often some blistering, but the survival rate is consistently good and other surgeons have given reports of satisfaction. The color of the graft is red for a good while and may possibly need permanent pigment injection, but so far this has not had to be resorted to.

The size of the transplants have been increased some, extra skin as a full-thickness graft has been taken over and beyond the cartilage. But great bulk probably can not be successfully transplanted consistently. The length does not make any difference, but the height or distance from the nutrient edge does.

This free transplantation of the composite graft points to the possibility that has been noted clinically occasionally of the successful replacement and grafting of completely severed parts of the ear. These losses of the ear should have attempted replacements locally if the tissues are clean enough and not too macerated. If they can not be restored locally, burying them in the subcutaneous tissues can be considered for possible later use. This conversely can also be applied to clean losses of parts of the nose, and it has been applied to, and recorded of, the tips of the fingers.

While the repair of defects of the nose are described here, the use of the graft in other areas is under investigation, such as the repair of deformities associated with cleft lip.

Sensation in these small grafts usually becomes normal if the supplying nerves are present in the area.

SUMMARY

Drawings of operative procedures and illustrations of clinical results are shown of composite free grafts of two surfaces of skin and cartilage, from the ear, with restorations of the border of the nose and the columella in single procedures.

# UNUSUAL SURGICAL LESIONS OF THE UMBILICUS*

## REPORT OF CASES OF CONGENITAL ORIGIN

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EVERY DISCUSSION of diseases of the umbilicus should begin with reference to the definitive work of Dr. Thomas S. Cullen,[1] published in 1916, because with the exception of additional case reports very little has been added to the subject. Previous to Cullen's book a senior member of this Association, Dr. George Tulley Vaughan,[2] reported a case of cyst of the urachus, collected 52 cases from the literature and presented a classification of abnormalities of the urachus.

During recent years many cases of congenital and acquired abnormalities associated with the umbilicus have been reported, the largest number in any one report being by Trimingham and McDonald.[3]

The embryologic background for these conditions has been frequently presented but for clarity should be reviewed briefly. During the early days of the embryo the yolk sac is the largest structure. The allantois grows from it into the body stalk and at almost the same time there is an infolding of the yolk sac to form the primitive intestinal tract. The growth of the embryo includes this segment in its body cavity or celom. The segment of the yolk sac which connects its main portion with the primitive intestinal tract becomes the vitelline duct. The growth of the midgut is primarily in the section of the celom outside the cavity of the embryo. The debouched gut lies in the extra-embryonic portion of the celom in the proximal end of the developing umbilical cord, the so-called umbilical celom. At about 2.5 months of gestation when the embryo is 45 mm. in length the small bowel recedes into the body cavity. The vitelline duct normally separates from the ileum and becomes completely obliterated.

The allantois opens into the anterior face of the primitive cloaca. The primitive cloaca is divided into the rectum (posterior portion of cloaca) and the vesico-urethral primordium (anterior portion). The allantois persists at the cephalic end of the primitive bladder. As the bladder grows the allantois degenerates, a remnant persisting in the form of a fibrous cord, the urachus, connecting the apex of the bladder with the navel. The urachus is flanked by the hypogastric ligaments, remnants of the umbilical or hypogastric arteries.

The vitelline (omphalomesenteric) arteries fuse proximally to become the superior mesenteric artery. The superior mesenteric vein develops secondarily in connection with the left vitelline vein which becomes part of the

* Read before the American Surgical Association, April 2–4, 1946, Hot Springs, Virginia.

portal vein. The parts of the vitelline veins distal to the anastomosis of the superior mesenteric and left vitelline vein degenerate as the yolk sac degenerates.

The closure of the abdominal wall to and around the umbilicus is a result of the growth and approximation of the ectoderm (epidermis) and mesoderm (derma, muscle, fascia, and peritoneum) and is relatively complete before the third month of gestation.

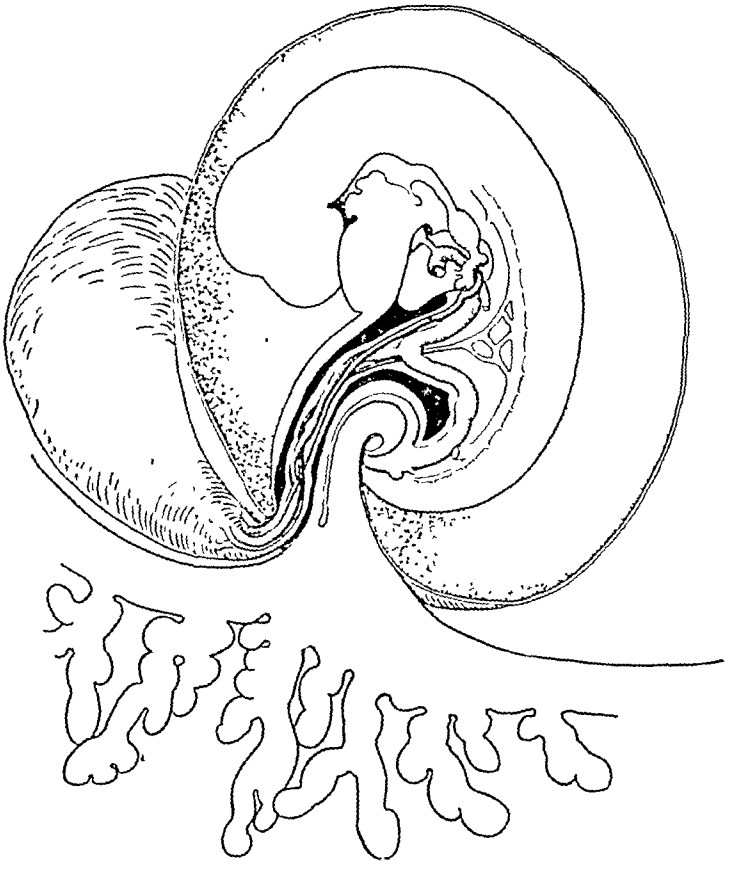


FIG. 1.—Five-millimeter human embryo, 33 days gestation (modified from Cullen).

The congenital abnormalities that occur in this region are results of faulty development. Figure 1 is a diagram of a 5-mm. embryo of about 33 days gestation. The allantois can be seen as a duct leading from the vicinity of the yolk sac through the primitive umbilicus to the cloaca. The vitelline duct connects the yolk sac and the small intestine (ileum) and the omphalomesenteric vessels accompany the vitelline duct. The midgut, consisting of the small intestine and the right side of the colon, is developing in the umbilical celom. The wall of the celom has grown and narrowed the ventral or umbilical defect in the celom to the primitive umbilicus which contains the umbilical celom.

After the cloaca has separated into the urinary bladder and the rectum, the allantois continues to connect the bladder with the umbilical cord. At birth the umbilical portion of the allantois has become obliterated. The abdominal portion is quite short and may be patent. As the bladder descends into the pelvis the duct or cord if it has closed, is drawn out in length.

Failure to obliterate may be complete or partial, and the persistence of all or part of this epithelial tube is the explanation of the conditions to be reported.

In the same manner the vitelline duct should separate from the ileum and degenerate. A persistence of all or part of this tube lined with intestinal mucosa explains certain congenital abnormalities.

As noted above the midgut should recede into the abdomen. If it is prevented from doing this, a hernia in the umbilical cord is present at birth. If there is a failure of the ectodermal and mesodermal structures to unite in the midline of the ventral surface of the embryo, a defect results which would be covered by amnion and peritoneum fused into a membrane.

## ABNORMALITIES OF THE URACHUS

Vaughan,[2] in 1905, before this Association proposed the following classification of these abnormalities:

1. "The Complete, in which the duct is open all the way, forming a continuous communication between the bladder and the outside of the body at the navel.

2. "The Blind Internal, in which the navel remains closed, but the duct communicates with the bladder.

3. "The Blind External, in which the communication with the bladder is closed, but the navel end remains open.

4. "The Blind, in which both ends are closed, but the duct remains open in the middle."

The Complete ducts are the most interesting of this group. Usually urine is passed both by navel and by urethra. Occasionally there is obstruction of the urethra so that all of the urine is passed through the navel, more often the tract is small so that only a few drops of urine appear at the navel. In planning excision of such a tract it should be remembered that in the newborn the bladder has not descended into the pelvis so that the patent urachus is short.

CASE 1.—*Patent Urachus:* W. J., white, male, an infant of nine months, was admitted to the Medical College of Virginia Hospital on December 4, 1945. He was a normal well-developed infant except for infection in and around the navel in the center of which was a sinus draining urine. He voided normally through the urethra. He was given penicillin intramuscularly, and wet dressings were applied to the infected area. After ten days the acute infection had subsided. He was then operated upon by Dr. W. F. Grigg, Jr., the Resident Surgeon. The navel was circumscribed by the incision which was extended downward in the midline. The duct was a thick cord, 4 cm. in length, adherent to the peritoneum, which had to be opened for its removal, and led to the dome of the bladder. Here it was ligated, cut away and the stump buried by silk sutures. The wound was closed in layers. On the seventh postoperative day the wound, which had become infected, disrupted, with evisceration of loops of small bowel. It was resutured and the patient then recovered uneventfully. Figure 2 illustrates this condition diagramatically and Figures 3 and 4 show the miscroscopic picture of the urachus at two levels.

The Blind Internal urachus opening into the bladder is probably of very frequent occurrence and goes usually undiscovered through life. Hammond, Gylesias, and Davis[4] found an urachal sinus communicating with the bladder in 10 per cent of adult specimens examined by them. Calculi may be formed in these sinuses, and such cases have been reported by Dreyfuss and Fleiss;[5] Atcheson;[6] Bandler, Milbert, and Alley;[7] and Wyatt and Lanman.[8] The opening into the bladder may be small and the patent urachus above dilated so that it has the appearance of an accessory bladder or a diverticulum. Such a case was reported by Meade.[9]

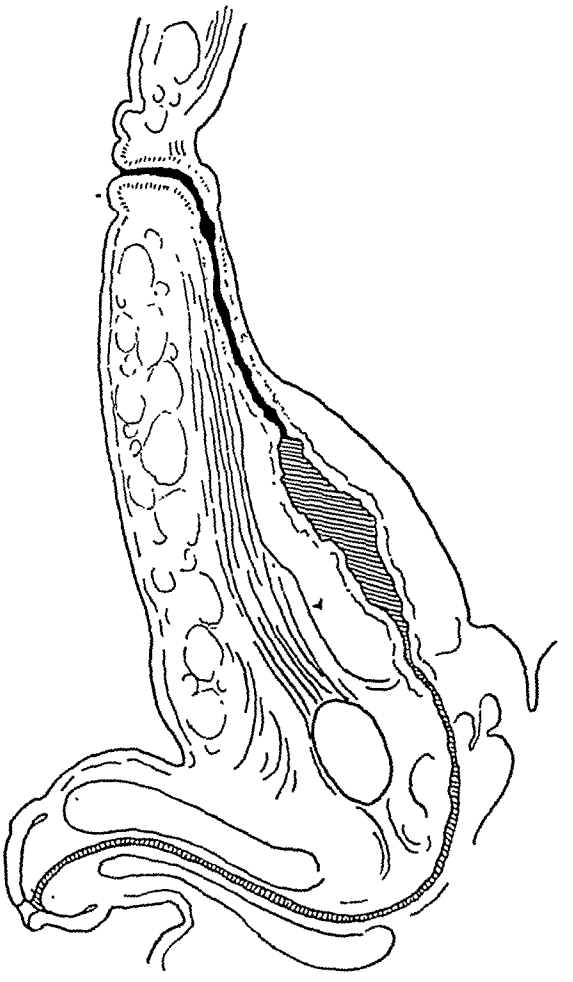


FIG. 2.—Urachus patent at birth.

The Blind External urachus opening at the umbilicus is rare. It may become infected and form an abscess. A case of tuberculous infection of such an urachus was reported by Winer and Danciger.[10]

The Blind Urachus usually results in the formation of one or more cysts. The size, number, and location of these cysts are determined by the amount and location of the persistent epithelium of the duct. They grow very slowly by accumulation of desquamated epithelium and secretion from the cells so they are usually manifested only in adults. The size varies from a few millimeters to enormous cysts which fill the abdomen. In the large cysts the epithelial lining has usually been destroyed. Rarely they become malignant tumors (Cullen,[1] Payne and Jones[11]). These cysts frequently become infected and filled with pus; after incision and drainage a sinus may remain or the cyst may recur. (Kantor,[12] Dudgeon, Jr.,[13] Yoerg[14].) An infected cyst which ruptured into the peritoneal cavity was reported by Powers.[15]

CASE 2.—*Cyst of Urachus:* Mrs. A. B., an elderly white woman, was admitted to the Memorial Hospital. She presented a large abdominal tumor which had been present for several years without symptoms. Recently it had grown rapidly in size and caused pain. It was thought to be an ovarian cyst but at operation through a low midline incision the cyst was encountered before the peritoneum was seen. It was densely adherent to the abdominal wall and obviously could not be removed. It was opened and approximately 3,000 cc. of cloudy thick fluid was evacuated. The

FIG. 3





FIG. 4

FIG. 3.—Low power photomicrograph of patent urachus from Case 1.
FIG. 4.—Another level of patent urachus from Case 1.

posterior wall of the cyst was obviously adherent to the peritoneum because coils of bowel could be identified through it. The entire incision was left open and the cavity packed with gauze. This packing was gradually removed, the external opening was kept patent, and the whole wound healed completely in about eight weeks. Microscopic examination of tissue from the wall of the cyst showed infected granulation and fibrous tissue but no epithelium.

CASE 3.—*Cyst of Urachus:* Mrs. R. L. M., white, female, age 30, was admitted to St. Luke's Hospital May 16, 1935. She presented a large abdominal tumor which had gradually increased in size. This was thought to be an ovarian cyst and was explored through a long midline incision. The findings were the same as in Case 2 except that the fluid in the cyst was much thicker and no pus was found. The wound was left open and the cavity packed with gauze. It healed to a small sinus which opened into a cavity about 10 cm. in diameter. The navel was not removed at the first operation. The wound was reopened, the navel excised and the remains of the cyst packed with gauze. The cyst then became obliterated but the sinus persisted for about two years before it healed. Microscopic examination of tissue from the wall at both operations showed granulation and fibrous tissue with no epithelium. No connection between the navel and the cyst could be found.

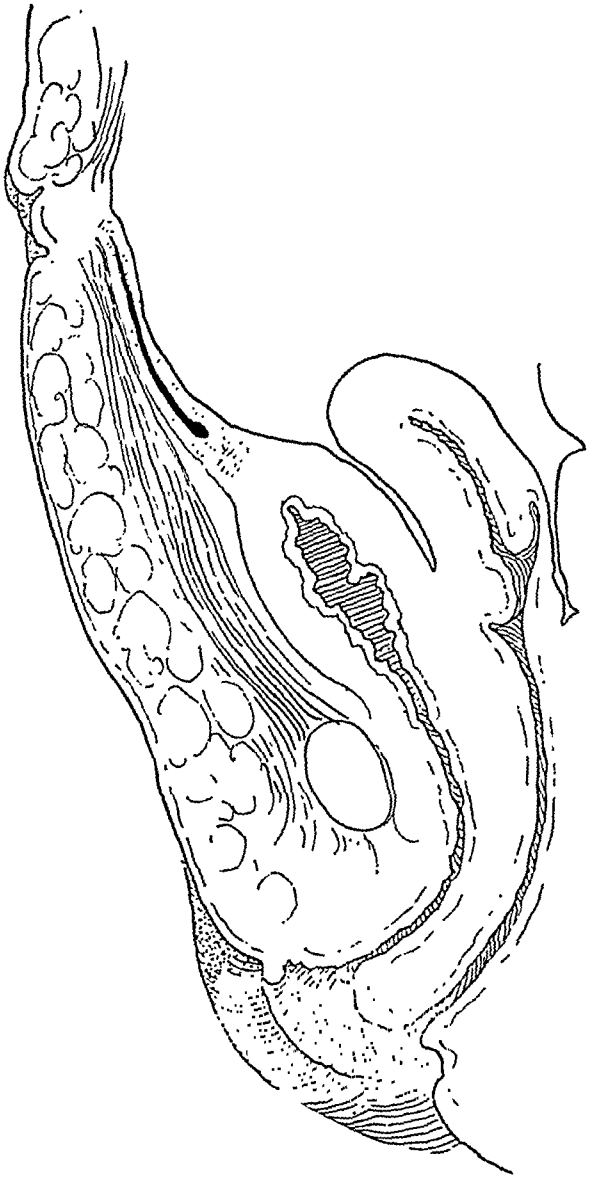


FIG. 5.—Diagram of urachus patent but closed at both ends. This duct may enlarge to a cyst in adult life.

Figure 5 shows, diagramatically, the patent urachus closed at both ends which in adult life formed the large cysts illustrated in Figure 6.

CASE 4.—*Cyst of Urachus:* F. B. S., white, male, age 41, was admitted to the Stuart Circle Hospital on September 5, 1945. He complained of pain in the upper abdomen. Examination revealed a smooth mass about the size of a large grapefruit in the midabdomen. This mass was freely movable and not tender. The navel was normal. The abdomen was explored through a midparamedian incision. The tumor was a thin-walled cyst attached to the under side of the navel by reflection of the peritoneum. The urachus thinned and disappeared into the wall of the cyst and below, to the bladder, it appeared normally obliterated. The cyst measured 15 cm. in diameter and contained clear fluid. Microscopic examination of its wall showed fibrous tissue but no epithelium. Figure 7 shows, diagramatically, the patent portion of the urachus responsible for this cyst and Figure 8 is a photograph of the cyst. Figure 9 is a photomicrograph of the wall of the cyst.

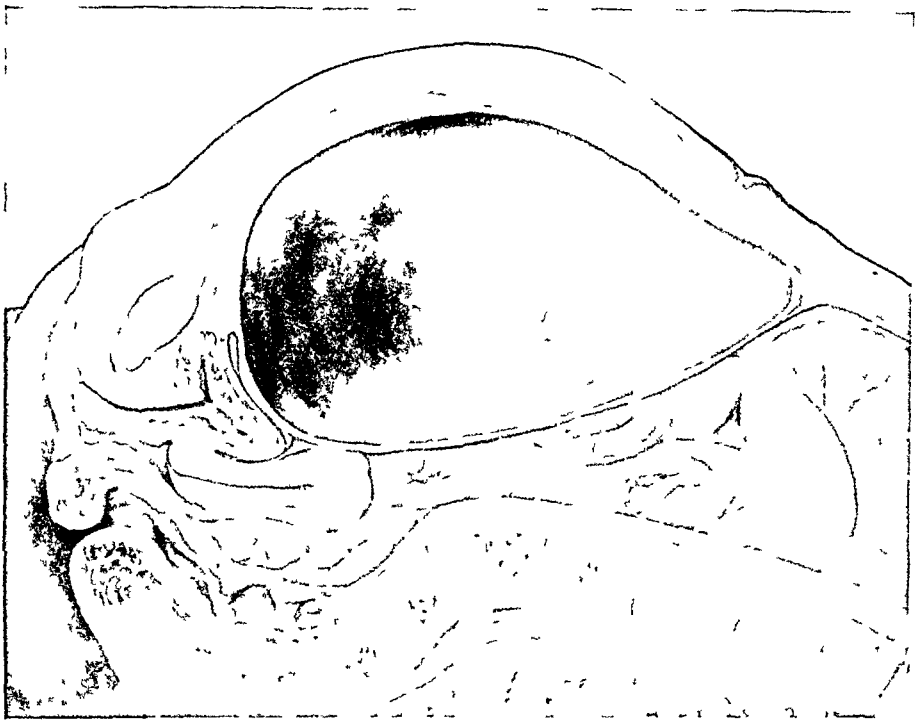


FIG. 6.—Drawing illustrating large cysts of urachus found in Cases 2 and 3.

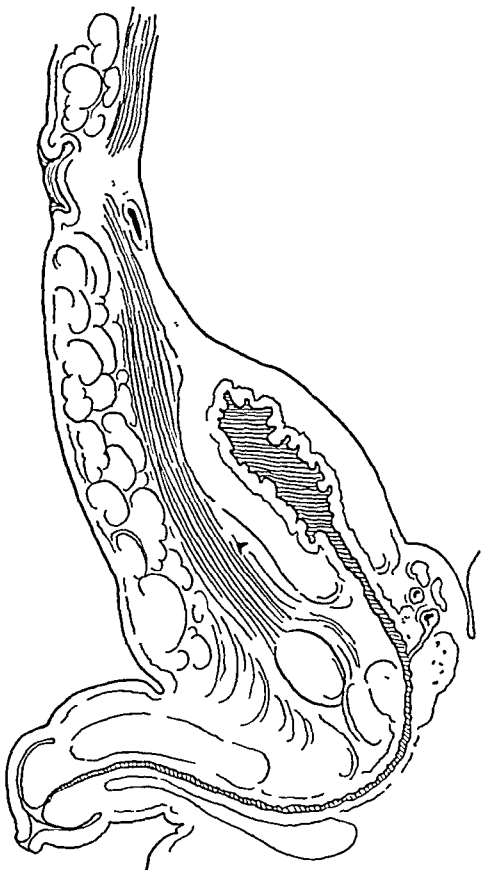


FIG. 7.—Diagram showing the patent portion of the urachus which formed cyst from Case 4.

COMMENT: Excision of these lesions is the treatment of choice. They are frequently complicated by infection of the tract or cyst and operation should be delayed until the infection has been controlled. Abscesses of urachal cysts should be drained preliminary to excision because usually the peritoneum must be opened for excision. When the cyst has grown to large size excision is either impossible or too hazardous so marsupialization must be done.

### ABNORMALITIES OF THE VITELLINE DUCT

The vitelline duct may remain patent from the navel to the small bowel, it may be obliterated at each end and form a cyst, small portions may persist in a cord and form small cysts, the external end may remain in and beneath the navel to form a

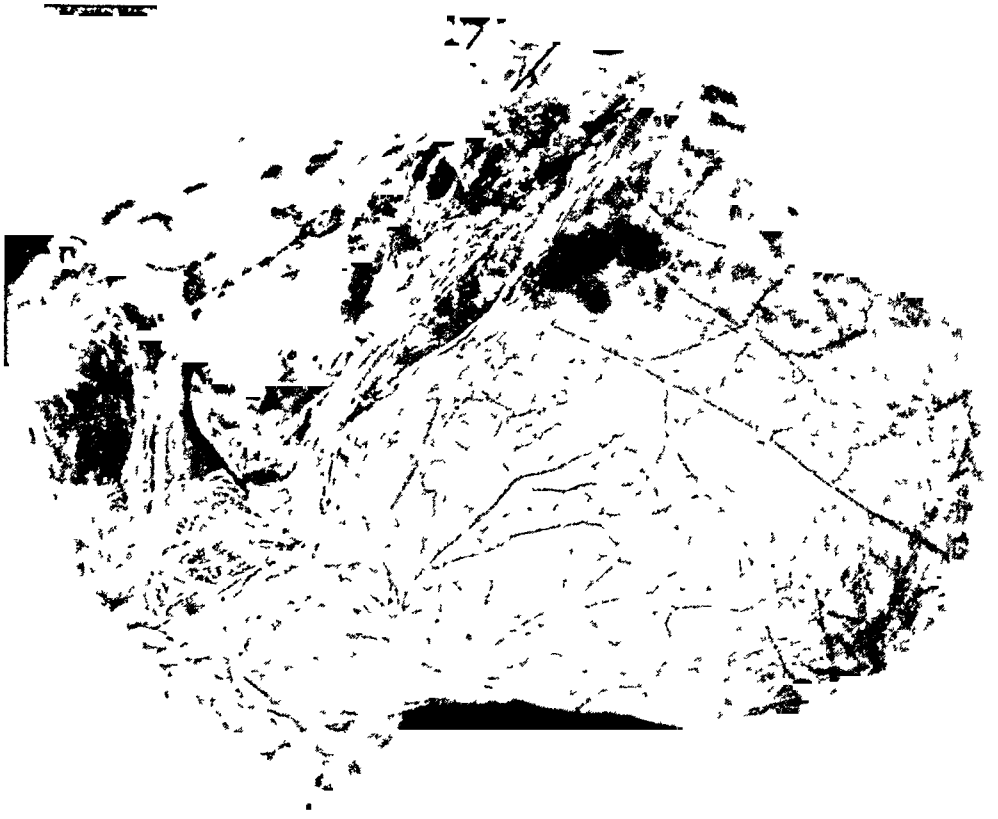


FIG. 8.—Photograph of cyst of urachus from Case 4, 15 cm. in diameter.

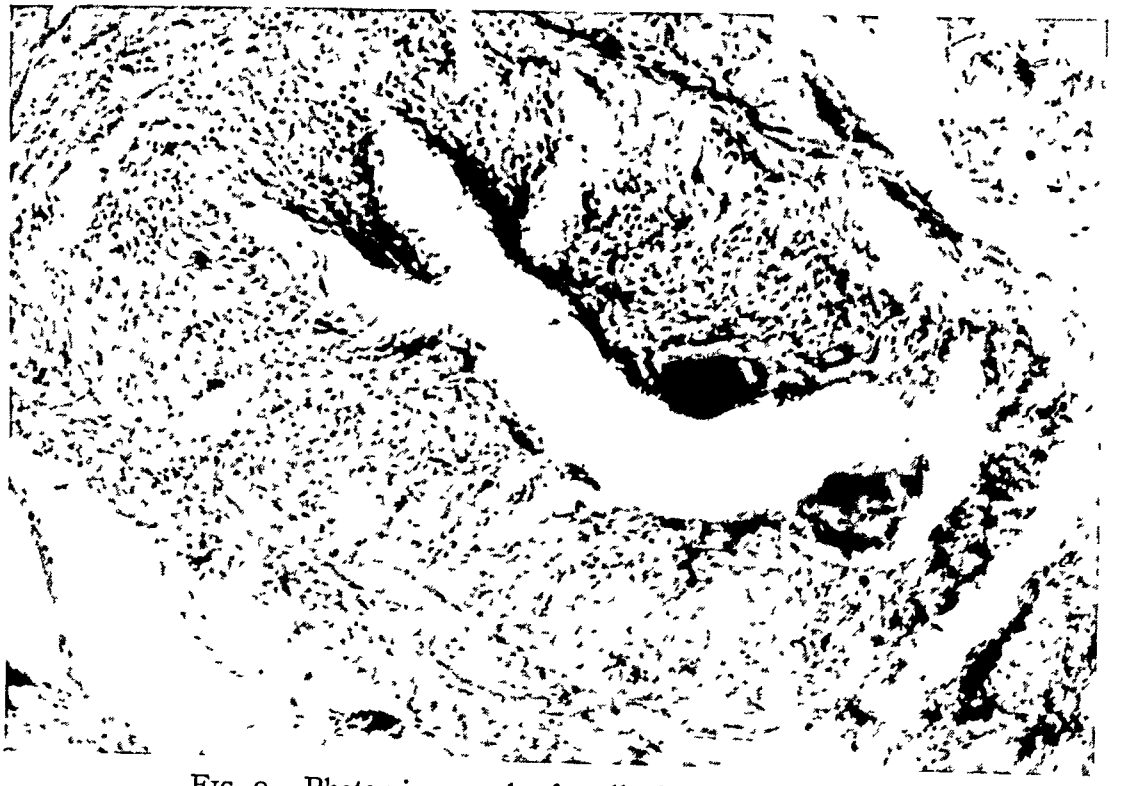


FIG. 9.—Photomicrograph of wall of cyst from Case 4.

sinus, a cyst or a small tumor (Fig. 10), it may remain as a cord attached at either or both ends, the blood vessels may remain as a cord, Buchanan and Wapshaw[16] and as occurs most frequently the distal end may remain to form the diverticulum of the ileum described by Meckel.

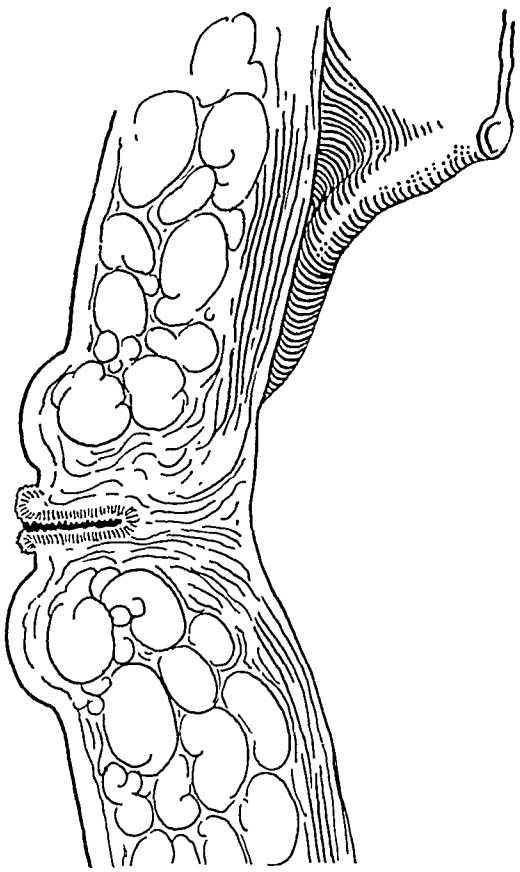


FIG. 10.—Diagram of remnant of the vitelline duct in the navel.

CASE 5.—*Vitelline Polypus of Umbilicus:* Baby V., white, male, age 2 years, was admitted to Stuart Circle Hospital on April 21, 1944. Since birth this baby had had a soft red area in the navel which bled easily. The mass was about 1 cm. in diameter and had the appearance of granulation tissue. Probing did not reveal a sinus and no mass could be palpated beneath the navel. Microscopic examination of the tissue taken for biopsy showed typical small bowel glands (Fig. 11). The navel was excised through an elliptical incision and there was no abnormality other than the small gland tumor.

CASE 6.—*Vitelline Polypus of Umbilicus:* Baby Miller, white, male, age 11 months, was seen on December 12, 1945. The history, examination and biopsy (Fig. 12), were identical with Case 5. He has not been operated upon on account of recurring upper respiratory infections.

CASE 7.—*Vitelline Cyst of Umbilicus:* Baby A. G. M., white, female, age 14 months, was admitted to Stuart Circle Hospital on October 11, 1945. Since birth this child had had a white discharge from the navel and on several occasions there had been acute infection. Examination showed a sinus leading into a cavity about 1.5 cm. in diameter in the navel. No mass beneath the navel could be palpated. The diagnosis was vitelline duct cyst and the navel was excised through an elliptical incision. Microscopic examination showed small bowel glands (Fig. 13).

COMMENT: The presence of small glandular tumors or cyst of vitelline duct origin is sufficient evidence to indicate excision of the navel and exploration at least of its peritoneal surface. Caustics are not sufficient to destroy this tissue, and cauterization might easily result in penetrating the peritoneal cavity. There may also be other remnants deep in the navel or on its peritoneal surface, as in the case reported by Barney Brooks[17] which had pancreatic tissue beneath a small cyst. The small tumor may be the end of a more or less patent duct, as reported by Morgan,[18] or the end of a cord leading to a Meckel's diverticulum, as reported by Lange and Eastman-Nagle.[19]

CASE 8.—*Primary Carcinoma of the Umbilicus:* L. H., colored, female, age 65, was admitted to St. Philip Hospital on January 3, 1945. She complained of soreness and discharge from the navel of three months duration. Examination showed a deep

navel with an ulcer in its center measuring about 1 cm. in diameter, deep red in color. The edges were sharp and the whole area was very firm to feel (Fig. 14). There was no history indicative of intra-abdominal lesion and abdominal and pelvic examinations were negative. The navel was excised through a wide elliptical incision. The peritoneal surface of the navel was normal. A limited exploration of the abdomen revealed no evidence of malignancy. The pathologic diagnosis was adenocarcinoma

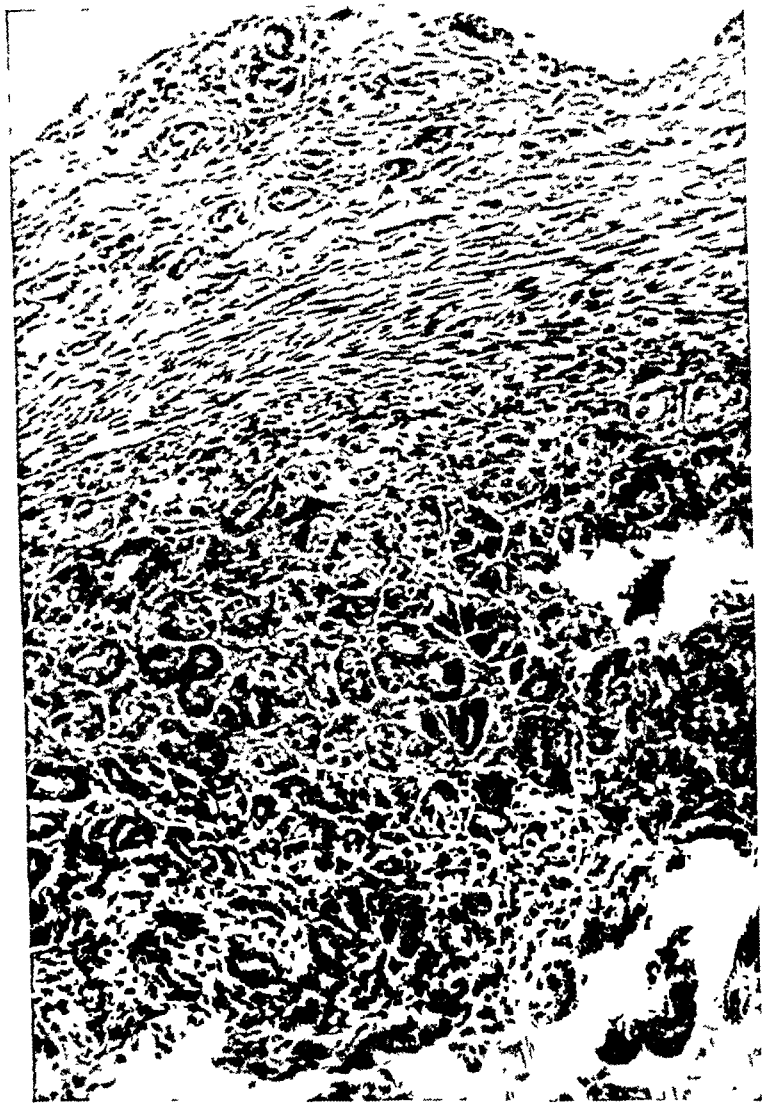


FIG. 11.—Photomicrograph of polypus from Case 5.

(intestinal type) (Fig. 15). Roentgenologic examinations of the gastro-intestinal tract after barium meal and enema were entirely negative. Her recovery was uneventful except for mild wound infection. Three months after operation a hard mass developed under the scar. Roentgenotherapy of this mass resulted in decrease in its size. Ten months after operation there was marked ascites and, after removal of 4,000 cc. of fluid, a firm mass could be felt beneath the navel extending upward in the right side. She died one month later at home. No postmortem examination was made.

COMMENT: This case seems to be one of primary adenocarcinoma of the navel from vitelline duct remnant, although incomplete exploration and lack of postmortem examination leave some doubt. In favor of its primary nature are the absence of history to indicate an intra-abdominal lesion, absence of physical signs, negative roentgenologic examination of the gastro-

intestinal tract, the local recurrence, and the infra-umbilical mass found after removal of ascitic fluid. Undoubtedly the majority of malignant lesions in the umbilicus are metastatic from primary intra-abdominal growths. I have explored two such cases. In one, the primary growth was in the

FIG. 12

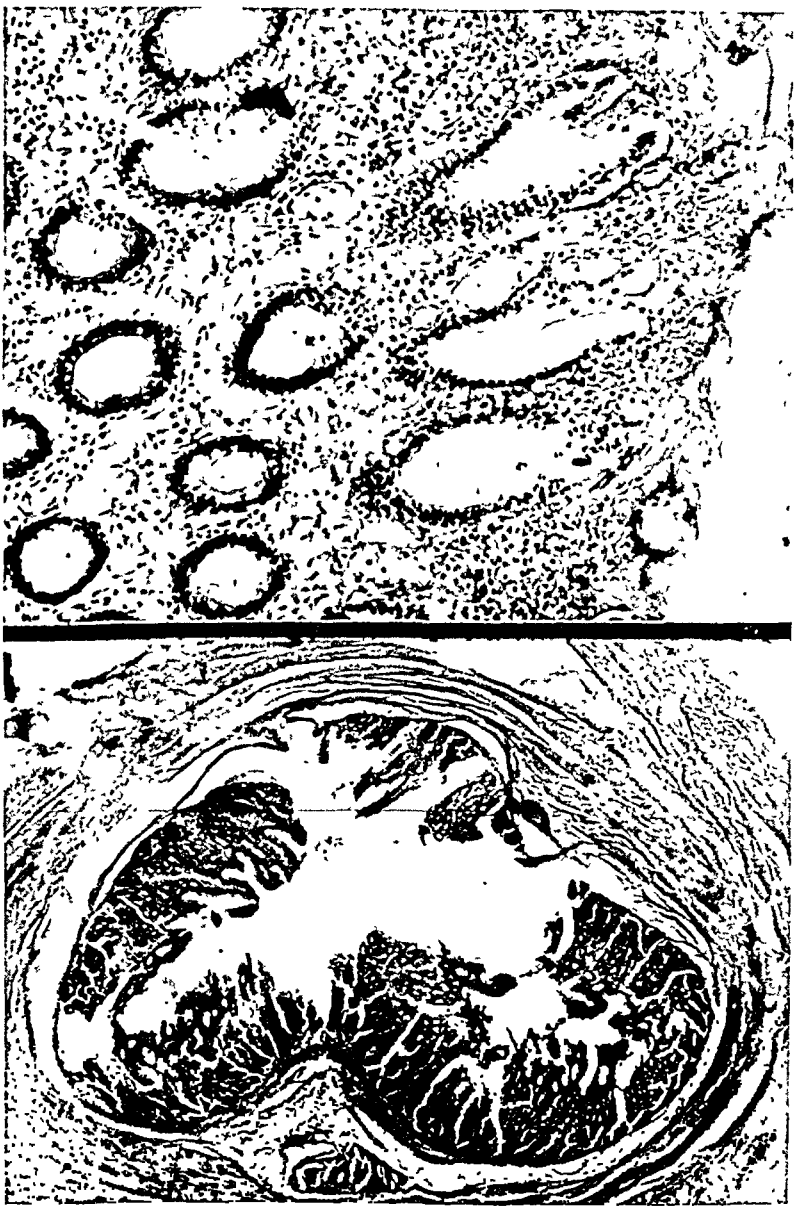


FIG. 13

FIG. 12.—Photomicrograph of polypus from umbilicus of Case 6.
FIG. 13.—Photomicrograph of wall of cyst from Case 7.

small bowel; in the other, it was in the left kidney; and both had metastases in the liver and omentum. Lombardi and Parsons[20] reported metastasis from the stomach, Rochet and Francillon[21] one from the bile tract, and Cullen[1] collected a number of cases both primary and metastatic.

# LESIONS OF THE UMBILICUS

## UNUSUAL HERNIAE AT THE UMBILICUS

The ordinary umbilical hernia is due to a defect in the fascia beneath the navel. The rare ones are due to gross abnormalities of embryonic development. Probably the most important factor is the failure of approximation of mesodermal structures. This may be due to large size or abnormal shape of viscera, particularly the liver, or to small volume of the abdominal cavity, or to some unknown factor in embryonic growth. Like other congenital defects it is at times one of multiple lesions.

CASE 9.—*Hernia into the Umbilical Cord:* Baby Y, Negro, male, age 6 days, was admitted to St. Philip Hospital on November 24, 1929. The baby was normally developed except for the presence of a mass in the stump of the umbilical cord measuring 7.5 x 6 cm. Its wall had the appearance of a huge umbilical cord which was bile-stained, necrotic in spots, and ulcerated over the distal portion, where there was a fecal fistula (Fig. 16). At operation, a transverse elliptical incision was made around the umbilicus, and the peritoneum opened. Numerous coils of small bowel were in the sac. They were adherent to its wall and to each other by fibrinous adhesions. The peritoneum was deeply congested and edematous. At the distal end of the sac a Meckel's diverticulum

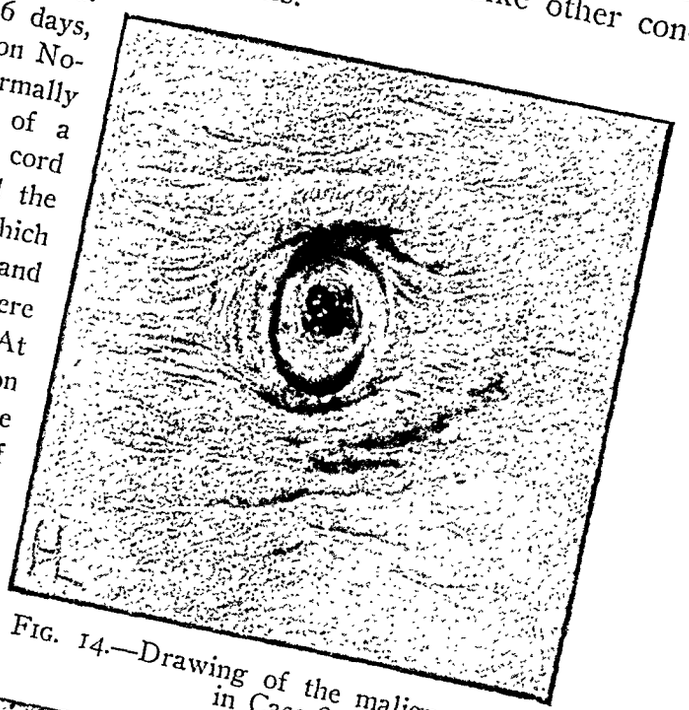


FIG. 14.—Drawing of the malignant ulcer in Case 8.

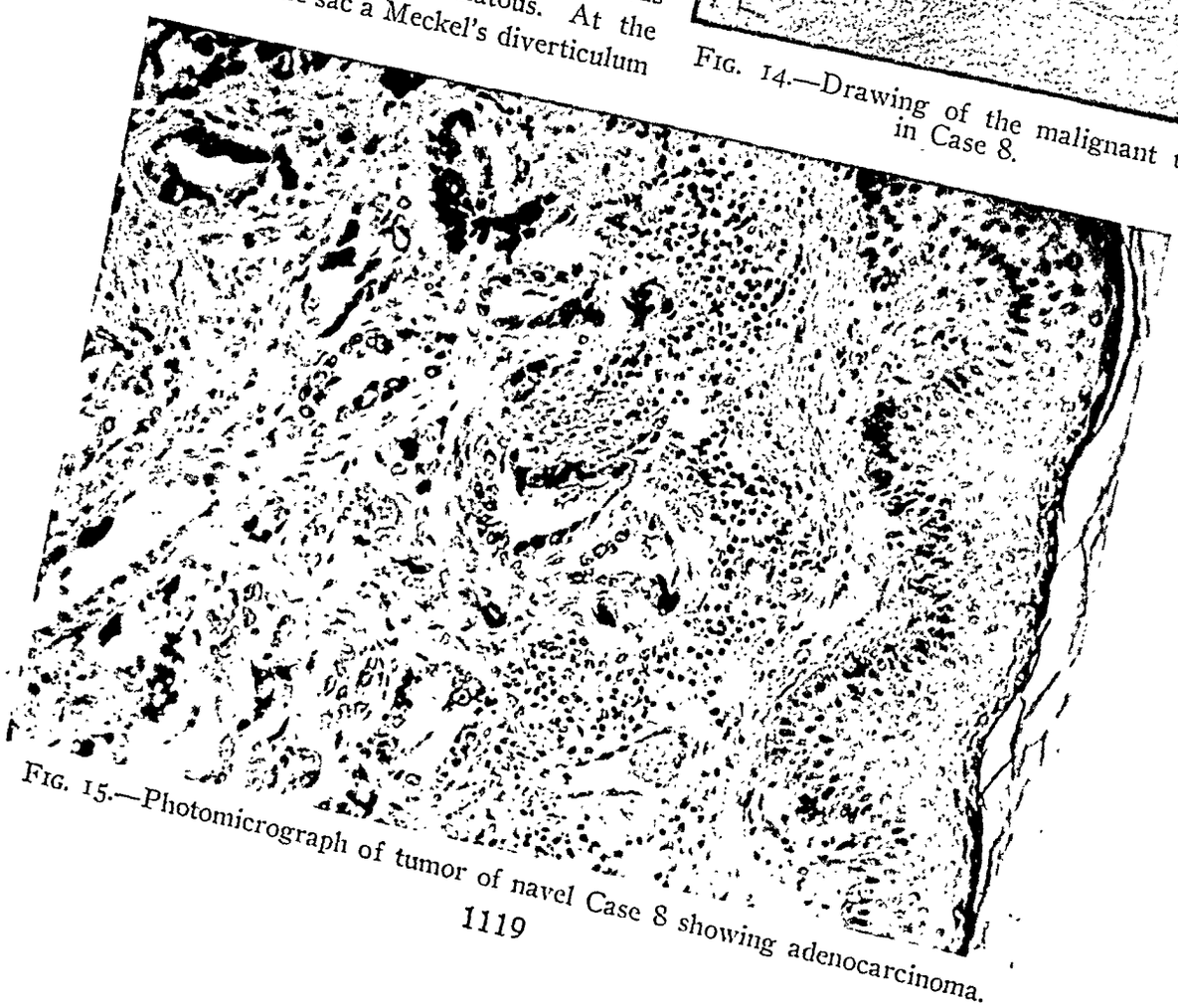


FIG. 15.—Photomicrograph of tumor of navel Case 8 showing adenocarcinoma.

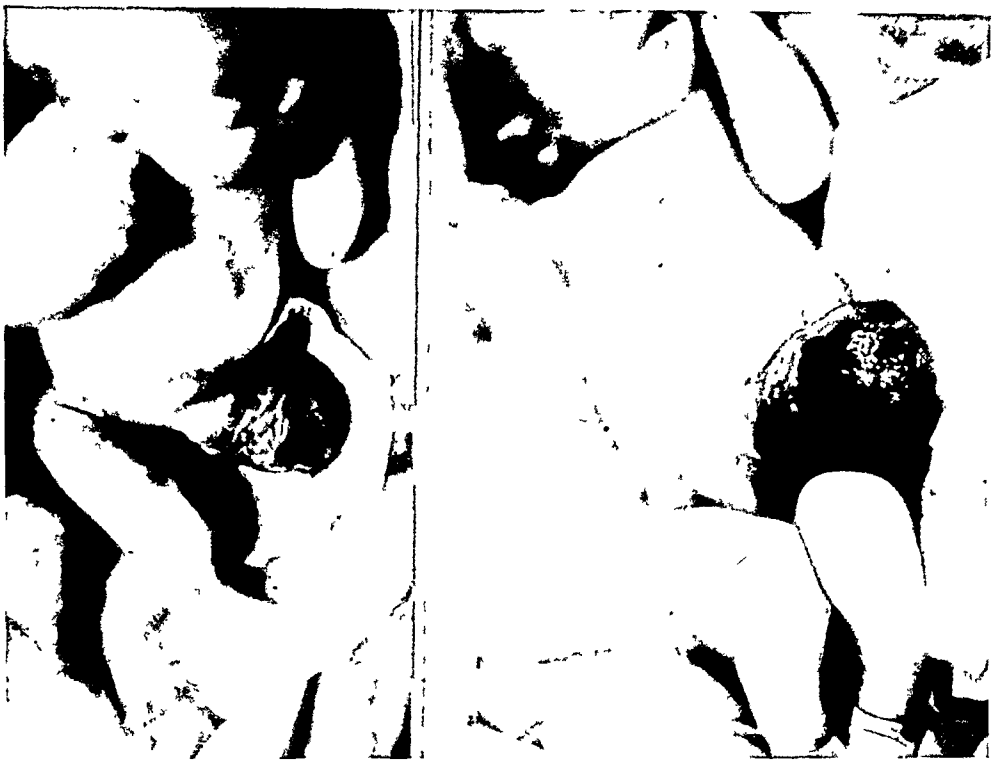


FIG. 16.—Photograph of Case 9.

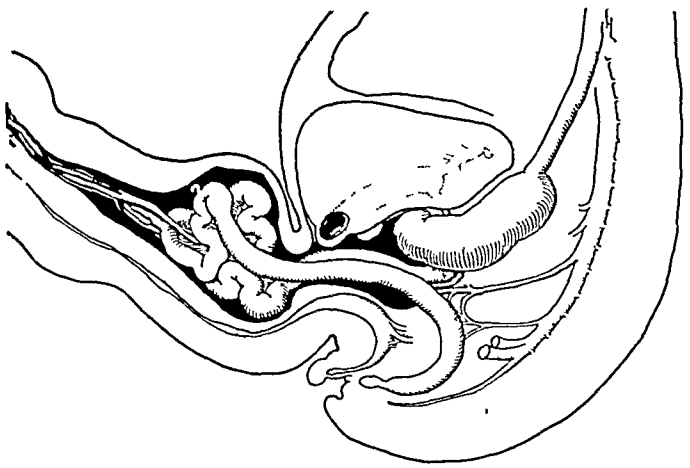


FIG. 17.—Diagram of 23-mm. embryo, this normal embryonic location of the midgut remained at birth of Case 9.

was present which was open through the wall of the mass. The adhesions were separated, the diverticulum amputated, and the coils reduced into the peritoneal cavity. The umbilical defect was closed by overlapping the wall, as in the repair of an ordinary umbilical hernia. The baby made a good recovery, except for thrush infection in its mouth, and left the hospital on the 12th postoperative day.

COMMENT: As previously noted the small bowel is developed in the exocelom located in the proximal end of the umbilical cord. When the embryo is 2.5 months of gestation, the bowel normally recedes into the ab-

dominal cavity and the exocelom is obliterated. In this case the vitelline duct was adherent or too short to allow the bowel to recede, so that the embryonic state remained. When the cord was cut distal to the mass the duct was divided leaving the fecal fistula. The Wharton's jelly which forms the wall of this hernia in the cord degenerates soon after birth. It is, therefore, important to operate as soon after birth as circumstances permit. Figure

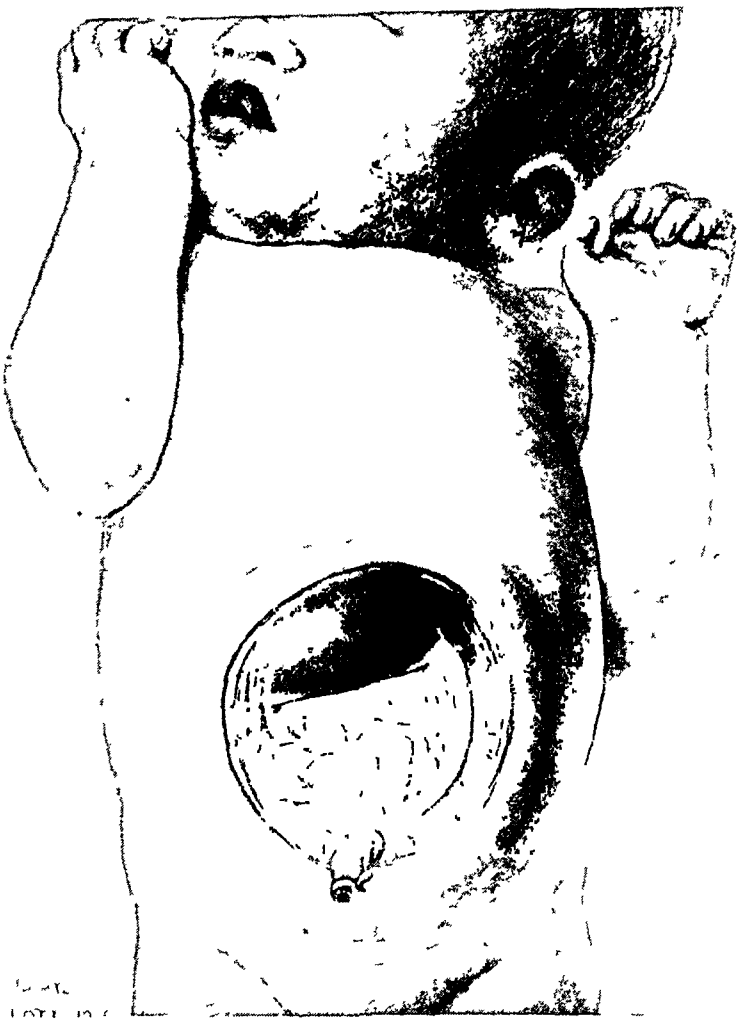


FIG. 18.—Drawing of Case 10, showing the abdomen covered by a thin transparent membrane.

17 illustrates, diagramatically, the state in a 23-mm. embryo of 47 days. This remained at birth in this case and explains the hernia into the umbilical cord.

CASE 10.—*Amniotic Hernia:* Baby W, Negro, female, age 2 days, was admitted to St. Philip Hospital on September 24, 1929. The baby had taken feedings vigorously and had passed normal stools and urine. It was well-nourished and well-developed except for the defect on the anterior abdominal wall. There was a circular window, about 7.5 cm. in diameter, covered by a thin transparent membrane through which the liver and the intestines could be clearly seen. The stump of the umbilical cord was attached at its lower portion. There was no protrusion of the abdominal contents (Fig. 18).

When the baby arrived in the operating room the next day, its temperature, which had previously been normal, was 100.6° F., and the membrane over the abdomen had become yellow and opaque. There was obviously infection present, but closure of the defect seemed imperative. In order to prevent opening the peritoneal cavity a circular incision was made leaving about 0.5 of skin attached to the edge of the membrane. The surrounding skin was undermined and sufficiently mobilized to allow easy union down the midline.

The baby's condition declined rapidly and it died 12 hours after operation. Postmortem examination showed a pocket of pus within the membrane and general peritonitis. The only abnormalities noted in the viscera were a globular shape to the liver which was normal in weight (12 Gm.) and partial failure in rotation of the right side of the colon.

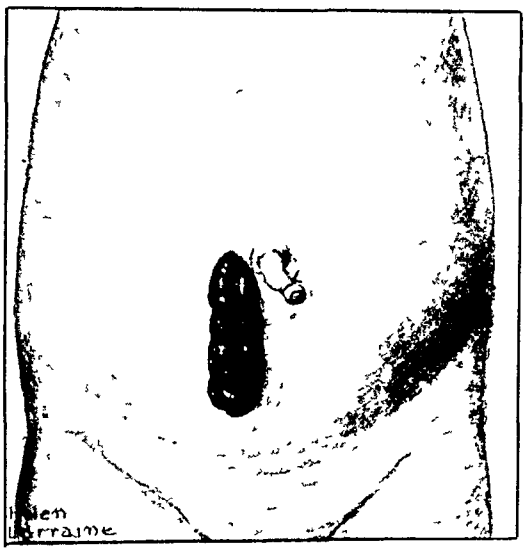


FIG. 19.—Drawing of Case 11 showing omentum protruding through a complete defect in the abdominal wall.

COMMENT: This deformity is a very interesting one. It is a rare condition but occurs with sufficient frequency for surgeons and obstetricians to be familiar with the dangers associated with it. Johns[22] recently reported such a case operated upon immediately after birth, and the baby survived. He reviewed the literature and collected 96 cases. The majority of cases have visceral deformities and enlargements which made closure difficult and at times impossible. The case reported here would have been a very favorable one because there was no bulging of the covering membrane from such visceral abnormalities and closure was easy. However, the delay in hospitalization after delivery and the day in the hospital before operation gave the opportunity for development of infection of the membrane and the peritoneum which caused its death.*

CASE 11.—*Complete Defect through the Abdominal Wall:* Baby P, white, male, was delivered at the Medical College of Virginia Hospital on July 28, 1945. At birth a yellow-red protrusion presented to the right of a normal umbilical cord. The next morning the protruding mass had increased in size; it measured 2 x 7 cm., was deep red in color, firm to feel, and narrowed at its point of emergence through the abdominal wall to the size of the opening, about 1 cm. Gentle traction brought out what was obviously normal omentum. There was also marked diastasis of the rectus muscles above the umbilicus (Fig. 19). A transverse elliptical incision was made excising the umbilicus and the opening. The pedicle of the mass of omentum was close to the transverse colon but it was easily excised. The transverse wound was closed as is usually done for an ordinary umbilical hernia. There was no other abnormality noted. This baby made an uneventful recovery.

COMMENT: There is no satisfactory embryologic explanation for this

* Case 9 and 10 were reported in Surg. Clin. North America, 10, 805–809, August, 1930.

defect. I am not aware of any similar case reported, but the literature has not been completely reviewed.

## CONCLUSIONS

These cases and many others in the literature indicate the following conclusions:

1. The patent urachus and cysts of the urachus are frequently infected, this infection should be controlled by appropriate measures before radical operation is undertaken because it is usually necessary to open the peritoneum in excising the urachus or its cysts.
2. Large cysts should be marsupialized because complete excision is hazardous or impossible.
3. The frequency of patency of the urachus near the bladder indicates care in preserving its continuity when incisions are made near it, and if it is divided as in transverse incisions it should be carefully ligated to prevent possible leakage of urine into the peritoneal cavity.
4. The navel containing remnants of the vitelline duct should be completely excised because the tract extends deeply into the navel and is frequently associated with an abdominal persistence of the duct or its blood vessels.
5. Adenocarcinoma of the navel while more frequently metastatic may be primary.
6. Babies with amniotic hernia, hernia into the cord, and eventration of abdominal contents through the wall should be operated upon immediately after birth before infection has developed.

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# BOOK REVIEW

OPERATIVE GYNECOLOGY. By Richard W. Te Linde, M. D. J. B. Lippincott Co., Philadelphia, Pa., 1946.

IN a new "Operative Gynecology" Dr. Te Linde has produced an original work which, in the experience of this reviewer, is unique among surgical treatises on gynecology. The author apparently planned his work without regard to previous methods of presentation of the subject, and has produced what may well be a new classic on the subject.

In preliminary chapters he discusses in detail preoperative and postoperative care, the instruments employed and anesthesia. Each of these chapters is carefully illustrated and gives complete instruction on patient care and the development of particular procedures.

The later chapters are based not primarily on specific technical procedures but on the various organic conditions for which gynecologic operations are needed. The book becomes, therefore, of value not only because of its description of surgical technics but also for the clinical consideration of the various conditions to be treated.

Retrodisplacement of the uterus, for example, is considered first, from the standpoint of anatomy and then symptomatology, before the various surgical procedures are taken up. Similar handling is given to other subjects, as prolapse, the relaxation of the pelvic floor, and the various tumors. Pathologic consideration is given to the nonmalignant lesion of the cervix, to cancer of the cervix, the histology of the endometrium, and endometriosis, before the technical aspects of the surgery of these lesions is taken up. Ovarian tumors are discussed as a subject instead of there being simply a consideration of ovariotomy. Other chapters are devoted to surgical conditions close to but not in the immediate field of gynecology, namely, the surgery of the abdominal wall, of the anus, intestines, and the appendix.

The whole work is magnificently illustrated, principally with new drawings. The approach to the subject is an entirely fresh one, and Dr. Te Linde has made a most important contribution. The work will probably remain for a long time a standard and, perhaps, the principal work on gynecologic surgery.

HOWARD C. TAYLOR, JR., M. D.

# STUDIES ON THE EFFECTS OF ADULT ANIMAL TISSUE EXTRACTS ON WOUND HEALING*

## A PRELIMINARY REPORT OF THE FACTORS RESPONSIBLE

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IN NORMAL HEALTHY INDIVIDUALS who have sustained injuries to tissue or organs, the process of repair proceeds through an apparently orderly sequence of biologic events to the point of healing, where the speeding-up of regenerative processes stops. The work here presented is based upon the assumption that it may be possible to influence this cycle directly in one or more of its phases, in order to accelerate the healing process.

This hypothesis is not new for, in 1925, Baker and Carrel[1] reported an apparent growth-accelerating effect of embryo-web porridge evident both *in vitro* and *in vivo* experiments. Other investigators also demonstrated an accelerating effect of embryonic extracts on wounds. However, during this period it was felt that if growth-promoting substances were present in tissues there should be more in embryonic cells.

In 1939, in a series of *in vitro* experiments it was shown by one of us (R. S. H.), and others,[16] that adult animal extract, has a greater stimulating effect than embryonic juices, and that this effect is not only present on standard chick fibroblast cultures but is noticeable on explanted human epithelium.[10] Furthermore, it was found that adult animal tissue extracts of sheep, beef, rabbit and dog were as effective on chicken fibroblasts as were homologous extracts.

It was logical, from the results of these *in vitro* experiments, to assume that clinical use might be found for the various extracts of tissue when applied to human wounds. From 1925 to 1932, many workers[2, 5, 19, 22, 24, 25, 28] used embryonic extracts of various tissues in an attempt to accelerate healing of so-called indolent wounds. However, the accompanying case reports are few and unimpressive. Furthermore, during this period less was known of the many systemic factors which influence final repair; hence, the criteria for refractivity were not sufficiently exacting. At the beginning of World War II interest in embryonic extracts was again revived when Waugh,[29] in 1940, reported beneficial results in refractory human wounds to which a desiccated embryonic extract prepared by Fischer[13] was applied. More recently, in 1945, reports from Russia, by Goldberg,[14] describe successful treatment of indolent wounds with an ointment containing embryonic extract.

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Objections to the embryonic extract however have been raised since it is difficult to prepare in quantity, expensive, relatively unstable, and, as pointed out, it has less stimulating effect than have adult extracts.

In a series of experiments and clinical trials we have used a tissue extract prepared as follows: Sterile adult sheep hearts are finely minced in a blender with Tyrode's solution. After standing in the refrigerator for 24 hours the mixture is centrifuged and the supernatant extract decanted into convenient sterile flasks. This extract when kept refrigerated maintains its activity for one month, while a lyophilized ether-extracted fraction is active for a year. Both types of extracts were used in these experiments and were tested for potency.

As previously reported by us,[17] in 1944, the effect on dogs was studied by using bilateral areas of skin excision, one of which was treated with extract and the other by saline packs. It was found that in every animal the treated side was healed before the control in an average of 40 per cent less time (Chart 1).

At the same time, a number of clinical wounds were being treated, particularly those which appeared to be indolent or refractive to other types of treatment. Friendly skeptics would rarely call us to treat a wound until all other more orthodox methods had apparently failed. It soon became apparent that there was a definitely beneficial effect, which was obvious to many clinical observers. Concurrently, investigators[26, 21, 18] abroad were also using adult extracts or fractions thereof on indolent wounds, with reported success. Kerr and Werner[18] in this group used extremely exacting criteria for their selection of cases, but again interpretation of results, however objective, was based on clinical impressions.

Carrel and Hartmann,[6] in 1916, showed that wounds followed a definite pattern in healing, which could be expressed in a graphic curve, and DuNouy[12] in the same year pointed out that this curve could be expressed in a mathematic formula.

$$S' = S\,[1 - i(t + \sqrt{T + t})] \text{ or } S' = S\,[1 - i(t + \sqrt{nt})] \text{ (If t is constant)}$$

Key: $S'$ = area t days later.
$S$ = wound area at a known time.
$T$ = age of wound from time of first observation S.
$t$ = time between measurements.
$n$ = number of time-periods.
$i$ = a fixed coefficient which depends on the size of the wound and the age of the patient.

These observations were made on many carefully studied wounds which were followed to final healing.

In an effort to find some type of control for our treated clinical wounds, their expected healing time was plotted by the use of the above formula, and contrasted with the actual healing time of the extract-treated wounds. The results (Charts 2 and 3) appear to validate the clinical impressions. Furthermore, in a few instances, we were fortunate enough to obtain patients with bilateral lesions in comparable body areas. Using one wound for a control and

treating the other with extract, again a favorable difference was noted (Chart 4).

In this connection, Kerr and Werner[18] have concluded that upon the application of their extract "to one of several coexistent indolent wounds the process of healing resulting in the treated wound has been accompanied by the commencement of healing in others." They suggest that the absorption of the growth-stimulating substance at the primary wound may be responsible or that, as Young, Fisher, and Young[30] suggest, a growth-stimulating substance is liberated in the course of healing. We have found that in cases of multiple lesions, one may be stimulated to healing, while others remain relatively refractory.

Finally in an effort to evaluate the assumed stimulating effect of adult animal tissue extract without relying on clinical impression, secondhand controls or animal experiments, a group of five human volunteers were obtained for study. These subjects ranged in ages from 30 to 50 years, were in excellent nutritional states, and were all at absolute bed rest. Under novocaine anesthesia, and complete sterile precautions, wounds were made on both anterior thighs of nearly equal size and depth. These varied from 3 to 4.5 sq. cm., and from simple complete skin excision, to removal of a block of tissue down to the deep fascia. After 48 hours the larger side was chosen for treatment and the contralateral lesion was used for a control method which consisted of constant dakinization. Dressings were done twice daily. The treated side was dakinized for 10 to 15 minutes and then flushed with saline. Following this an extract-saturated gauze square was placed in contact with the lesion and covered with paraffined gauze. The control lesion was treated by leaving a Dakin pack on the wound without washing with saline. It should be stated that under this therapy, there was no evidence of infection present in these wounds at any time. At regular intervals the surface circumference of these wounds was traced on a transparent plastic disk, the area measured with a planimeter and the wound sizes were marked on graphs (Charts 5, 6, 7, 8 and 9) so that the healing in both wounds in each individual could be followed. Obviously, by this method, no provision was made for volumetric measurement particularly in those subjects in whom deep blocks of tissue were removed.

Four of the five treated wounds were healed before the controls, and in

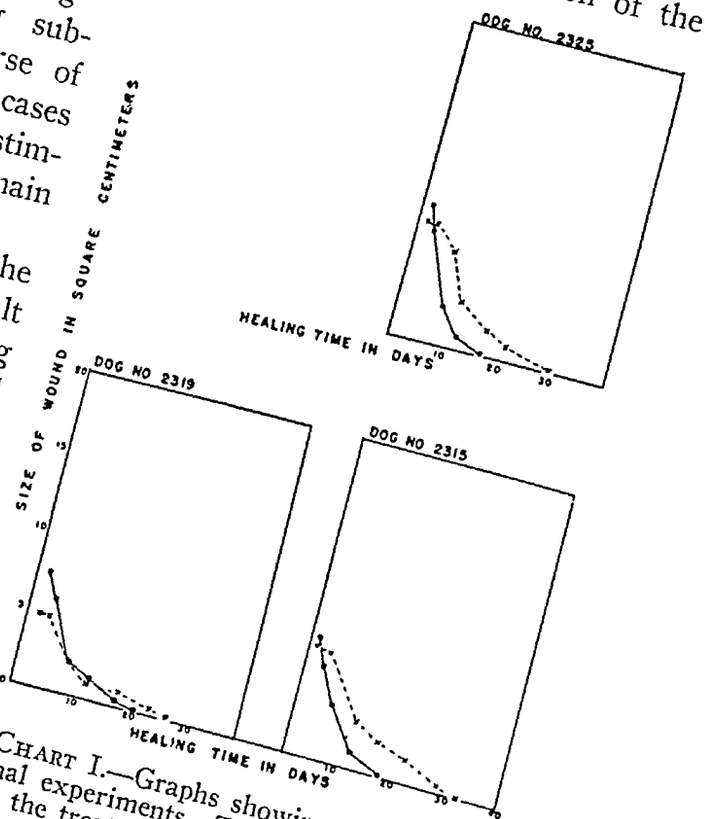
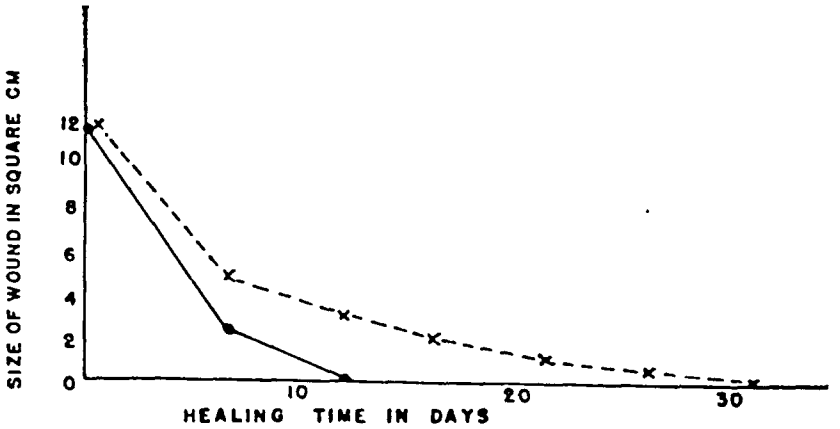



CHART I.—Graphs showing three of the animal experiments. The black line represents the treated wound and the dotted line the controls.

one case healing was simultaneous. In this subject (Chart 7), there appeared to be a mechanical impediment to epithelization. It had been noticed in observing the healing of some clinical lesions, particularly those which were deep and required filling in before epithelization, that the extract had a marked stimulating effect on granulation tissue growth. It was felt that the apparent accelerat-

CHART II



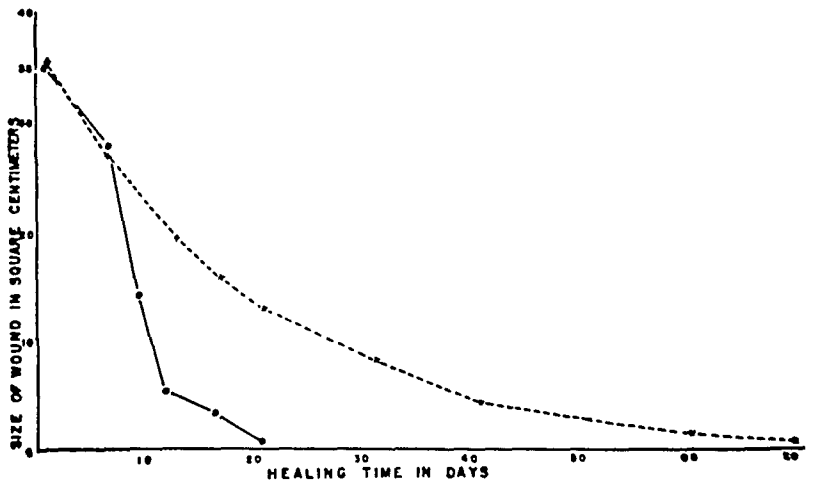




CHART III

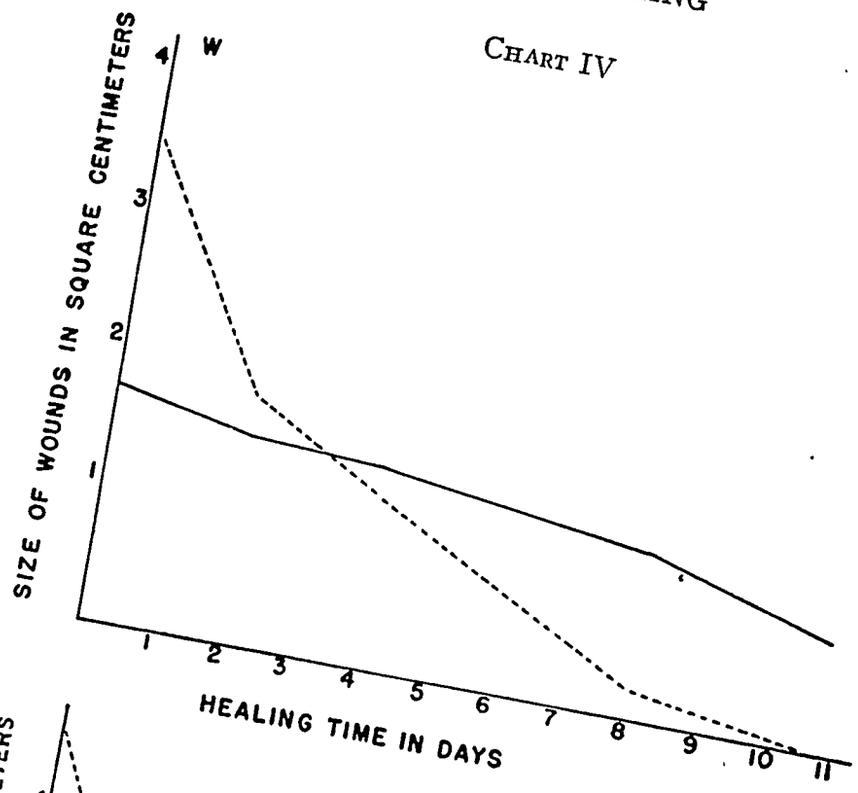
CHART II.—Case of E. K.: Solid line shows the actual healing time and the broken line represents the expected healing time. (DuNouy)

CHART III.—Case of A. W.: Solid line shows the actual healing time and the broken line the expected (DuNouy) healing curve.

ing effect of the extract in these wounds was due in part to the relative rapidity with which granulation tissue filled cavities. Accordingly, in the last two of the volunteers, blocks of tissue were excised to the deep fascia, and in these cases granulations were flush with the skin long before the control, and the epithelium had consequently crossed the denuded areas faster. In one case, where only full-thickness skin was excised, the excessive granulating effect was observed to impede the epithelization process, requiring actual excision of granulation tissue several times.

DISCUSSION.—From a survey of the literature it would seem that the

CHART IV



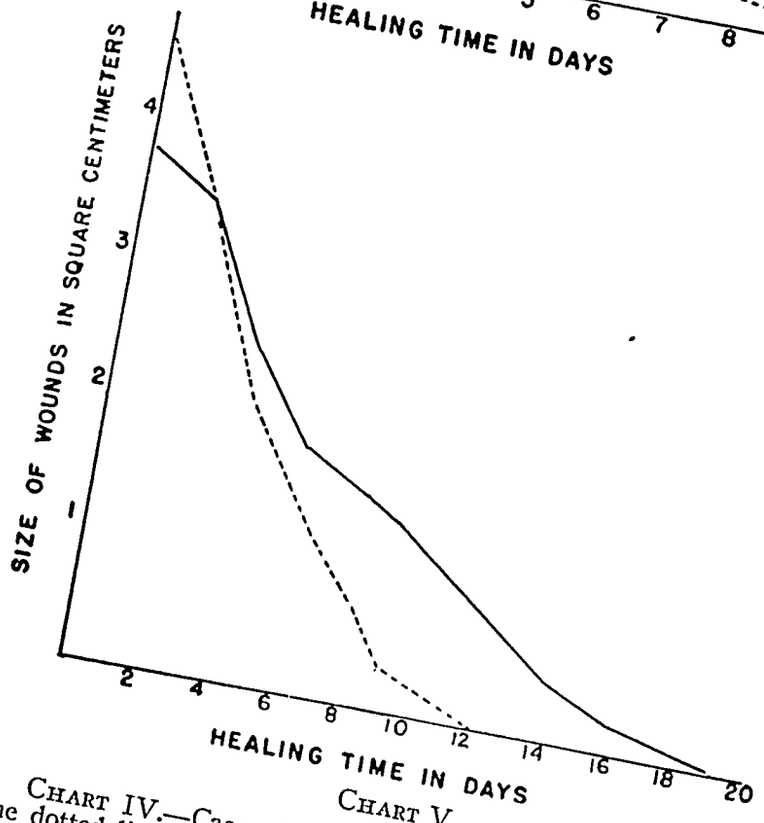




CHART V

CHART IV.—Case of W. (Patient with bilateral leg ulcers): The dotted line represents the healing curve of the treated lesion, and the solid line the control. The treated wound although over twice the size of the contralateral lesion was healed before the control showed much evidence of beginning healing. Notice that the untreated control side shows very little evidence of stimulation.

CHART V.—(Human Volunteer No. 1): Showing the decreased healing time of the treated wound (dotted line) as compared with the control (solid line).

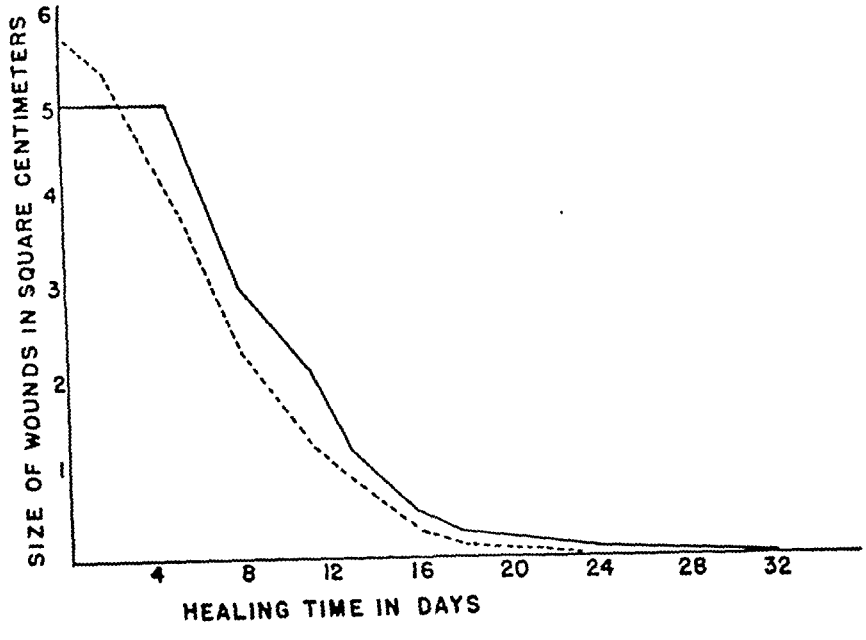
approach to the problem of wound healing has been largely an attempt to find and eliminate factors which can be shown to interfere with the healing of open wounds. It has been amply pointed out[4] that when a wound ceases to heal or remains stationary there may be a number of reversible conditions at play. The nutritional state of a person, with particular reference to protein and certain vitamins, must be maintained at a normal level and hematologic abnormalities corrected. Metabolic diseases such as diabetes and local circulatory disturbances play a part, and must be controlled before normal wound healing may take place. Finally, it is well known that the presence or absence of infection is of paramount importance, for the process of tissue repair will not take place when there is overwhelming local suppuration. Consequently, many of the medicaments which purport to accelerate wound healing are in fact agents which attempt to control local infection, thereby enabling the normal biologic healing sequence to intervene.

Certain other substances claimed to have growth-promoting properties are found in the literature. Some of these, such as chlorophyl,[27] allantoin,[15] preparations liberating sulfhydryl groups,[23] creatine[7] and, recently, human bone marrow antiserum[3] are presumed to have growth-stimulating properties acting in a positive manner on indolent wounds, rather than by neutralizing inhibiting factors. Many of these substances have not been proven to be active on cells growing *in vitro,* nor do some of the clinical cases treated meet the requirements necessary to draw conclusions.

As a working hypothesis, it may be stated that the process of repair begins with tissue damage. It would seem plausible, therefore, to assume that from injured cells a substance or substances are liberated which may initiate or influence the physical and chemical reactions of cellular proliferation. It has also been noticed both in cells growing *in vitro,* and wounds, that there is an initial quiescent or lag-period during which no cell growth takes place, normally of at least 48 hours' duration. Furthermore, it is certainly obvious that mature cells in an organism are subject to control by a local inhibitory mechanism which may oppose indiscriminate cell multiplication. Supportive evidence for this latter hypothesis may be found in the fact that malignant unlike normal cells exhibit no such latent period when growing *in vitro.*[11]

In other words, as an hypothesis, it may be assumed that tissue stability is a unique balance between local stimulating and inhibiting factors, with the latter normally in control. It may be that on injury stimulating substances are released locally, and become the preponderant force, thus, initiating the reparative process. Possibly, as a wound nears completion of healing the titer of stimulating substances falls off or the inhibiting factors assume more importance. Hence, in indolent wounds, it may be that the period of stimulation started by the release of local factors may cease and the healing process remains stationary either because the stimulating substances are used up, or inhibiting factors predominate. Evidence for this theory has been noted in the marked stimulation and improvement when indolent wounds are treated as compared to the lesser acceleration, possibly additive in effect, when freshly acquired wounds in healthy individuals are used.

CHART VI



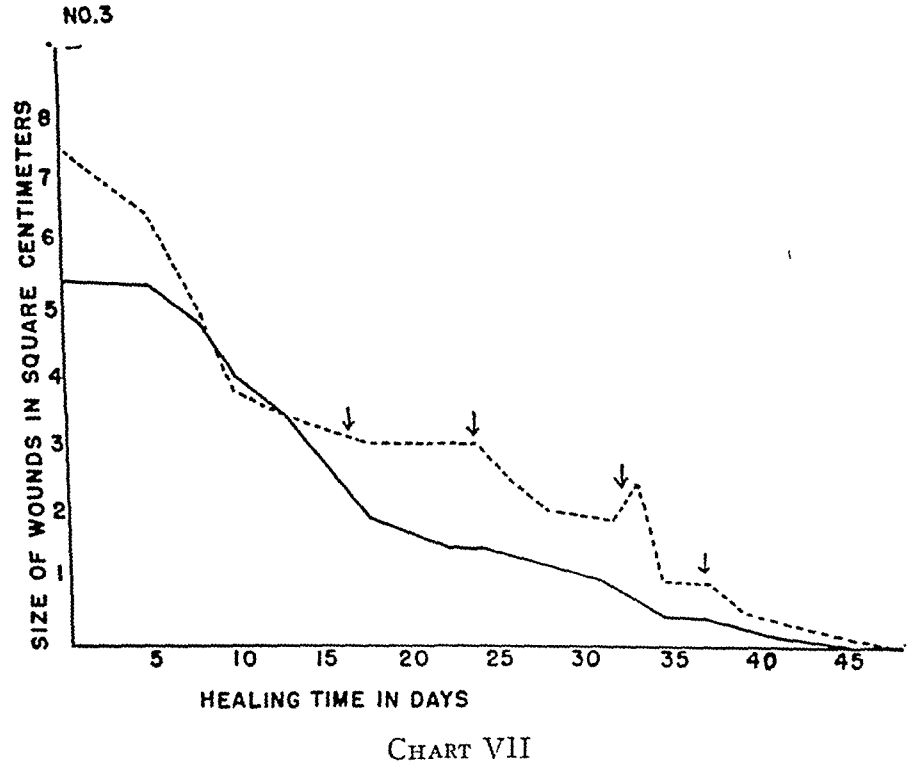



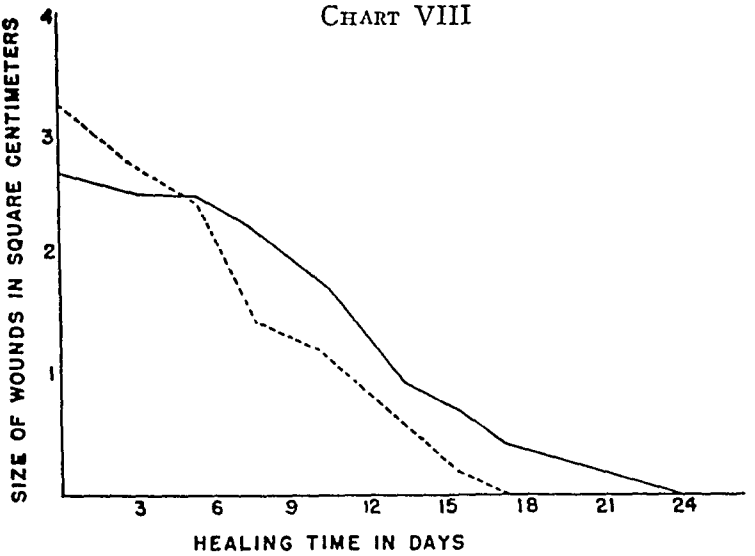

CHART VII

CHART VI.—(Human Volunteer No. 2): The broken line shows the healing time of the treated wound and the solid line that of the control.

CHART VII.—(Human Volunteer No. 3): The broken line represents the healing time of the treated wound and the solid line that of the control. The arrows point to periods of excessive granulation which mechanically impeded epithelization. Granulations were excised at these points.

Consequently, we feel that in adult animal tissue extract there is a substance (or substances) that exerts a growth-promoting effect when added to any heterologous tissue either *in vitro* or in human wounds. We further feel

CHART VIII



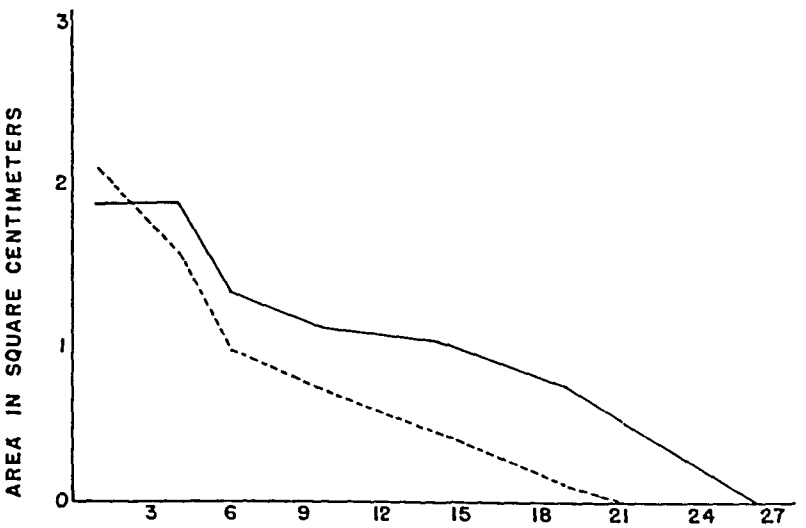




CHART IX

CHART VIII.—(Human Volunteer No. 4): The broken line shows the healing time of the treated wound and the solid line that of the control.

CHART IX.—(Human Volunteer No. 5): The broken line shows the healing time of the treated wound and the solid line that of the control.

that such substances act directly on the metabolic mechanism of cellular proliferation.

Many physical and chemical studies have been carried out by us in an attempt to isolate a presumed factor or factors responsible for the growth-

promoting effect of the total extract. The detailed reports of this work will be published elsewhere, but certain basic experiments warrant comment here. First of all, it should be mentioned that while Fischer,[13] Davidson,[9] and others who carried out extensive studies on the nature of embryonic tissue extracts, and Loofburow,[20] and Cook, *et al.*,[8] working with extracts of injured yeast cells, generally concluded that the active growth-promoting fraction was nucleoprotein; following our own studies we have concluded that this may not be the case.

In order to have a standard supply of material for laboratory and clinical investigation, a method was developed for preparation of extract on a large scale.* The initial extract was prepared in the manner described from fresh or frozen sheep heart which may have been stored for six months or more in a $CO_2$ ice box at −70°C. This extract was treated with ether which removed extraneous materials and also cleared-up slight contaminations. Following centrifugation the aqueous fraction, which was even somewhat more active than the original extract, was placed in small containers, frozen and dried *in vacuo*, the containers being sealed under sterile conditions. They contained extract in a powdered form which could be readily dissolved in distilled water. A standard strain of fibroblast cultures was used to test the material resulting from these experiments.

Heart extract is not thermostabile although heating to 60° for 30 minutes has no appreciable effect on activity. Heating-up to 70° C. for 5 to 10 minutes results in a 50% decrease in activity, and when carried out for a prolonged period of time results in a further diminution, but a certain degree of growth-promoting activity is still retained. A temperature of 100° C. does not produce complete inactivation but what remains is probably due to the ordinary nutrient materials which are present even in the heated extract rather than to any specific growth-promoting principle.

The extract is nondialyzable and loses its activity on passing through a Berkefeld filter over a wide range of pH from 3.8 to 8.0, though such changes in pH do not normally effect the growth-promoting activity of the extract. At this pH range about 50% loss in activity is observed in passage through a Seitz filter, but when a small amount of broth is first passed through a Seitz filter it is then possible to filter the extract at its usual pH 6:5 without any appreciable loss in activity.

The activity of the extract remains constant over a wide range of concentrations. Dilution of extract prepared by using one part cardiac muscle and two parts of Tyrode solution (1:2) with as much as four times the volume of Tyrode solution does not affect the activity. Further dilutions of this extract result in a gradual falling-off of activity. However, this extract diluted with 50 volumes of Tyrode solution still manifests some activity. Extracts more concentrated than 1:2 are injurious to cells.

Extracts prepared in the standard way contain about 30 to 130 mg.% of

*We wish to extend our appreciation to Lederle Laboratories Inc. for preparation of this extract in bulk.

protein, with a low protein content being usually less active. However, dilution of extract containing 130 mg.% protein with equal quantities of Tyrode solution did not result in a loss of activity; greater dilution of this extract did decrease activity but not in direct proportion to the diminished protein content, nor is the activity of the extract directly related to the general protein content, as may be seen after treatment with dilute hydrochloric acid. Here, lowering of pH from 6.5 to 4.8 causes precipitation, but, following centrifugation and readjustment of pH the supernatant fraction containing 0.5 mg. protein N. per cc. is quite as active as the original which contained 0.85 mg. protein N. per cc. Lowering of pH to 3.6 results in a reduction of protein N. content to 0.3 mg. per cc. without any loss of activity.

Extract was treated according to the method of Sevag, with an equal volume of chloroform and a small amount of octyl alcohol. This mixture was placed in a shaking apparatus overnight and then centrifuged for one hour. The entire procedure was carried out in the cold. Three fractions were obtained. The aqueous and interface fractions did not stimulate cells growing *in vitro*. The residue of the chloroform soluble fraction dissolved in Tyrode solution inhibited cell growth. No evidence was obtained of active nucleoprotein in the aqueous phase. Other proteins present in the interface fraction were denatured. Thus, absence of activity in this fraction does not preclude the possibility of the active factor being protein.

Twenty cubic centimeters of extract were adsorbed with 100 mg. of aluminum hydroxide in one case and with 20 mg. in the other. Both supernatant fractions actively promoted cell growth. The degree of activation was somewhat less than that of the original extract.

When the adult heart extract was centrifuged at 30,000 R.P.M. for 30 minutes, the supernatant fraction was found to be very active in promoting cell growth, while the macromolecular fraction showed only a slight degree of stimulating activity, such as might be due to the presence of nutrient material.

The total adult heart extract as well as the supernatant fraction obtained from ultracentrifugation were irradiated with ultraviolet light (2,640 A.°) for various periods of time up to 60 minutes. Following such irradiation, the extract did not lose any of its cell growth-promoting properties. Lyophilized heart extract may be redissolved in distilled water containing 50 mg. of sulfadiazine per 100 cc. without diminishing the activity of the extract or injuring the cells. Penicillin up to 300 Oxford units per cc. may also be added without detracting from the stimulating properties.

In view of recent ideas expressed, that growth stimulation may be produced by globulin, a brief study was made of the effect of the fractions isolated by Cohn, and his group, on cells growing *in vitro*. The gamma globulin fraction stimulates growth of cultures *in vitro* to a slight extent, but the degree of stimulation is much less than that of adult heart extract. Thrombin, also, has a slight stimulating effect, but even less than that of gamma globulin. Finally, fraction IV-I is somewhat more active than thrombin but its effect is not nearly so striking as that seen with adult tissue extract.

From the above data, it may be inferred that the active factor or factors involved in promotion of cell growth while protein in nature are not necessarily nucleoprotein. However, since it has been demonstrated that during cell proliferation or activity there is a large increase in the nucleoprotein content of cells it may well be that we are dealing here with an enzyme which plays a part in nucleoprotein formation.

## CONCLUSIONS

(1) Experimental and clinical evidence is presented which indicates that there is an active growth-promoting factor present in adult sheep heart extract.

(2) A method is presented whereby adult sheep heart extract may be prepared in large quantities and, thus, be available in stable form for clinical use and experimental study.

(3) This extract appears to exert a markedly stimulating effect on indolent human wounds, and a lesser effect on wounds of normal healthy individuals.

(4) From the experimental data available the active factor would appear to be a protein having many characteristics of an enzyme.

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# PRIMARY CLOSURE OF BEDSORES BY PLASTIC SURGERY*

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IN JUNE, 1944, at the Cushing General Hospital, Major W. B. Scoville began to experiment with the routine early closure of large decubitus ulcerations under the protection of systemic and local penicillin. Impressed by the early results, White, Hudson, and Kennard, in November, 1944, began an investigation of this revolutionary solution of the bedsore problem in sailors and marines with battle injuries of the spinal cord at the U. S. Naval Hospital, in Chelsea, Massachusetts. A report of the first five patients so treated and the impressive results achieved has already been published in the *U. S. Naval Medical Bulletin.*[1] † From this experience it was apparent that systemic penicillin in moderate dosage (120,000 Oxford units injected intramuscularly each 24 hours) effectively prevented sepsis in the widely undermined flaps of gluteal skin and subcutaneous tissue which were used to cover the defect left by the excision of large sacral decubitus ulcers. Provided the plastic closure was carried out with complete freedom from tension and with effective hemostasis, primary healing resulted within two weeks. In the presence of undue tension or with the formation of hematomas minor separations of the flaps occurred. These healed by granulation, contraction of scar tissue, and delayed epithelization within a period of a few weeks. There was no complicating major sepsis. At the time this preliminary report was written the authors felt that the method was safe and capable of producing a great acceleration in the rehabilitation of these seriously injured men. The most effective methods of swinging full-thickness skin flaps to cover sacral lesions had not been worked out and no attempt had been made to close large decubitus ulcers elsewhere, such as are found so frequently in battle casualties after a prolonged period of evacuation from distant outposts, especially in the tropics. As the U. S. Naval Hospital at St. Albans is a Plastic as well as a Neurosurgical Center, we have had a wide choice of material for further development of this valuable method. This report summarizes further experi-

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† In February, 1945, Lamon and Alexander[2] made the first report of the successful closure of such a lesion by these means in a patient in the McCaw General Hospital's Neurosurgical Section, which was then under Major Scoville's charge.

ence in nine patients with 14 such lesions in various areas over the sacrum, iliac crests, ischial tuberosities, hips, *etc.*

As one of us emphasized in the previous report,[1] decubitus lesions are frequent and serious complications in men who have received transecting injuries of the spinal cord overseas. This is particularly true of sailors and marines who have been sent home through the chain of evacuation hospitals from some remote part of the Pacific after exposure to a tropical climate, inadequate medical and nursing facilities. Under these circumstances bedsores tend to be large and multiple (15 in one marine wounded at Iwo Jima). The sloughs often extend right down to underlying bone, the granulations are avascular and unhealthy in appearance, and all are heavily infected. The tendency of these lesions to enlarge and for new ones to form is due in great part to malnutrition and protein deficiency, with the accompanying anemia and avitaminosis. In some of these unfortunate patients as much as a third of their body-weight may be lost, plasma protein may have fallen below the critical edema level, and the red count below 2.5 million. Protein-rich exudate is lost through the ulcerated areas as rapidly as after extensive severe burns, and all desire to eat and get well disappears. As with the victims of the German concentration camps, the first problem is to correct the nutritional deficiency and restore the individual's will to live. This preliminary period requires expert and unremitting nursing care plus constant effort to attain a satisfactory intake of calories and protein, as well as to administer adequate amounts of whole blood, iron, and vitamins. All possible sources of infection must be eliminated by the surgeon, and the urologist must attend to the difficult problems of tidal drainage, prevention of urinary sepsis, and stone formation. Much can be contributed by the Red Cross worker, chaplain, and psychiatrist in helping the patient regain his social and mental readjustment. Furthermore, war-time experience at Navy and Army hospitals has shown the value of physical exercise, which should be started in bed at the earliest possible moment. Once the nutritional deficiency has been corrected and the individual restored to a better all-around physical and mental state, the granulation tissue develops a healthier color and renewed growth, the sloughs tend to separate, and the skin edges to sprout-out new epithelium. This is the time for the radical plastic closure of these lesions, and it can usually be reached in a period of from one to two months' hospitalization, unless there are other complicating conditions. On the other hand, if standard conservative treatment is employed, even under most favorable circumstances healing will require many months (Guttmann[3]). When the thin layer of newly formed epithelium has ultimately covered the avascular bed of scar, it is liable to break down again and again as the individual begins to sit up and attempts to walk with braces. The same is true when these areas have been more rapidly covered by thin split-thickness grafts (White, Hudson, and Kennard[1]). We are now thoroughly convinced that, once the fundamental state of malnutrition has been corrected and recurrent sepsis from the urinary tract and other

wounds has been eliminated, the most effective solution of this problem is excision of the ulcerated areas and plastic closure by sliding in flaps of normal subcutaneous tissue and skin under the antibacterial protection of penicillin. The same is undoubtedly true of decubitus ulcers in civilian patients, although with proper nursing and better nutrition from the outset lesions of this type should rarely develop.

### SURGICAL TECHNIC

Plastic closure of bedsores can be undertaken as soon as the patient's general condition has reached the satisfactory status outlined above. He must also have accustomed himself to lying permanently in a prone or slightly lateral position. For several days before the patient is taken to the operating room, it has been our practice to make sure that the lower bowel is thoroughly evacuated by manual removal of fecaliths and colonic irrigations. In preparation for the operation the patient is given 30,000 units of penicillin intramuscularly and sedation with a barbiturate and morphine. No anesthesia is ordinarily needed. The scarred, infected edges of the ulcer are first trimmed with a safe margin, together with the superficial layer of granulations over its entire base. When, as is sometimes the case, there is undermining, the granulations under the flap should also be excised. Avascular areas where sloughs are adherent must be cut-back to a fresh vascular base. In one case (Patient 3, Figs. 1 and 2) we were forced to remove the coccyx and to rongeur away a portion of the lower sacrum on account of the presence of osteomyelitis.

Although preliminary cultures were always taken and the bacterial growth heavy, we have not found it necessary to pay any special attention to the type or number of micro-organisms, provided the flaps are sutured without tension and maintain an adequate circulation. However, in Patient 7, where mild infection developed secondarily to partial separation of the flaps, streptomycin might have been of help in cleaning-up the low grade colon bacillus infection in the necrotic edges of the flaps and permitting an earlier secondary closure (Fig. 3). The use of this drug might also have helped clear up the single instance of more severe infection with *B. proteus* and *anaerobic Streptococcus* which developed after closure of the second decubitus ulcer in Patient 5 and resulted in the only failure in this series. Unfortunately, streptomycin was unobtainable at that time. Sulfasuxidine, if given for a period before and after these plastic procedures close to the anus, might also prove helpful by reducing the number and virulence of the fecal bacteria.*

All of the patients in this group of cases had lost weight, many to a rather alarming degree, and all showed marked muscular atrophy. The skin below the cord lesion thus became quite loose and flabby, a fact that actually facilitated the closure and often made it possible to cover the smaller ulcers merely by

* We are indebted to Dr. Oliver Cope, of the Massachusetts General Hospital, Boston, for this useful suggestion, but have not yet had the opportunity to put it to the test.

undermining in all directions and drawing the skin margins together with sutures, as in the dorsal decubitis ulcer illustrated in Figures 1 and 2A.

One of the fundamentals of plastic surgery is accurate approximation of

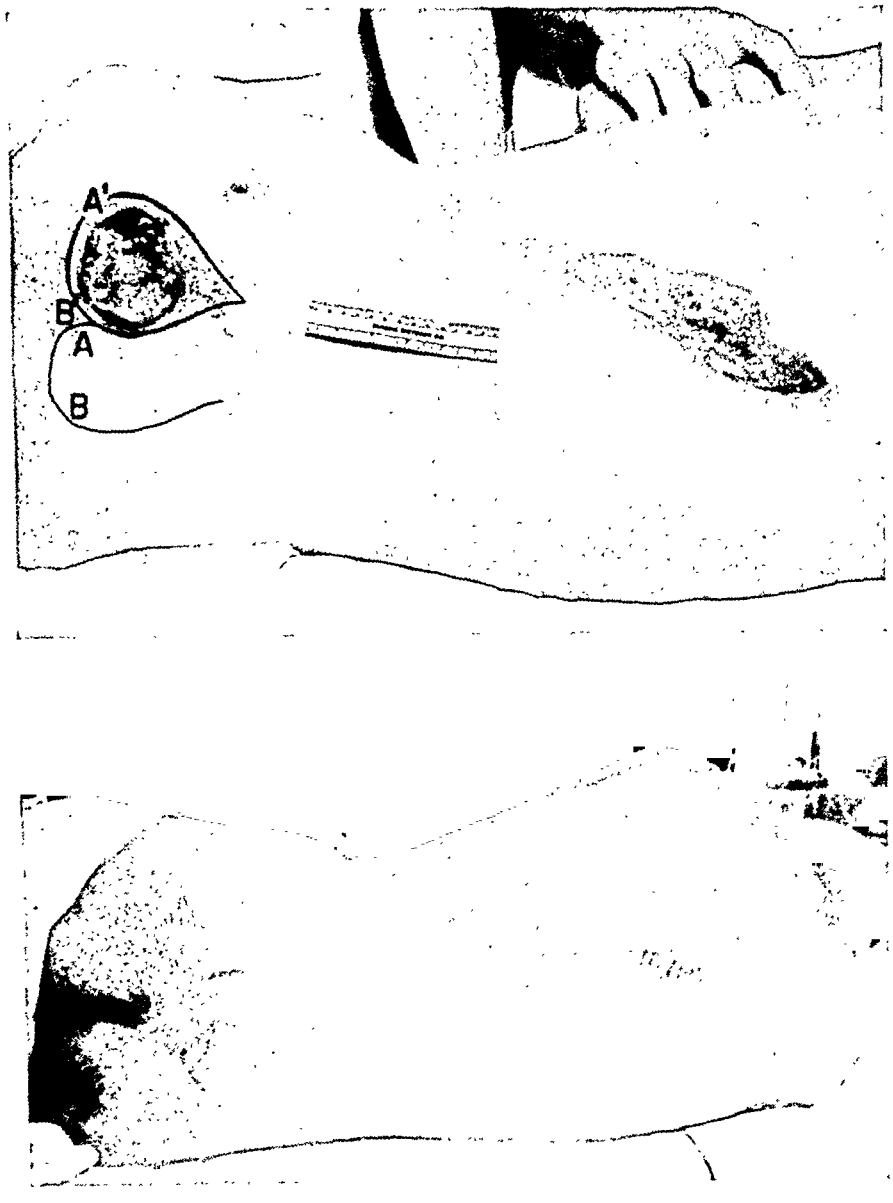



FIG. 1.—Case 3: (A) Preoperative photograph of patient's back showing lower dorsal and sacral decubitus ulcers. The area of excision of the sacral ulcer and the outline of the plastic flap are marked. It was necessary to remove the coccyx and to rongeur away the lower sacrum for osteomyelitis.

(B) Photograph taken three months later. The recent midline low thoracic incision through the area of plastic repair was made two weeks previously for laminectomy and exploration of the spinal injury.

skin margins without undue tension, and unless this rule is adhered to strictly the results are apt to be disappointing. In cases where it was felt that simple undermining and suture resulted in too much tension, one or more skin flaps

were outlined and switched over the ulcer, and the bed of the flap closed by drawing the skin edges together, after mobilizing by undermining (Figs. 2, 3, 4). The flaps must be planned very carefully and accurate measurements made before being raised. The pedicles of the flaps should, if possible, always

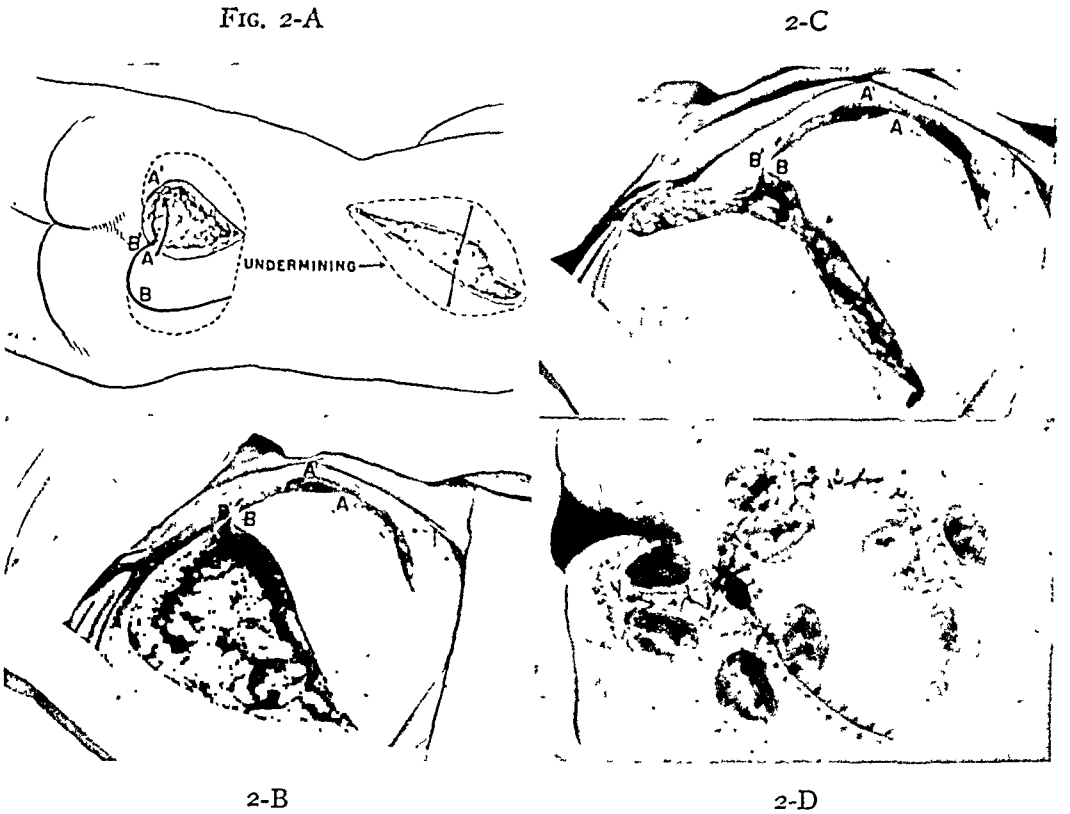



FIG. 2.—Case 3, continued: (A) Diagrams of areas undermined and the sacral flap raised.

(B) Photograph of sacral area on rotating the flap. Point A in diagram is slid to A', B to B'.

(C) The defect left after rotating the flap has been closed by subcutaneous suture with No. 00 plain catgut.

(D) The first dressing a week later: Part of the silk cutaneous sutures have been removed. The mattress stitches of stainless steel are shown with the buttons of roentgen ray film. These will be left in position for another week. There is a 1-cm. area of separation at the angle which was not undermined and which healed without any visible infection.

be in line with the direction of the arterial supply. Where possible, they should be raised in conformity with the natural lines of skin tension. The latter is of less importance than the former, since the end-result we are working for is closure of the ulcer rather than a good cosmetic appearance. In none of the cases in this series have we resorted to using the delayed-flap method, although probably this would have been a help in one case (Patient 7, Fig. 3). We feel sure that by delaying the flap—in other words, raising it in stages and not trying to complete the operation in one stage—we could close larger defects than those shown. It is our intention to do this in selected cases in the future. In planning the flaps we have not attempted to utilize any mathematic formula

as regards the surface area in relation to the size of the pedicle, but have relied on the color of the flap and the presence of active bleeding at its tip as evidence of sufficient blood supply. It goes without saying that the flap should be adjacent to the ulcer, and for midline ulcers over the sacrum and coccyx the best donor area is the buttocks. The base is placed above and the tip may




FIG. 3.—Case 7: (A) Outline of large double flaps with necrosis of edges, as seen at time of first dressing.
(B) Appearance of flaps one month later, prior to secondary plastic.
(C) Photograph showing healing two and one-half months after primary operation.

extend to the subgluteal fold (Fig. 2). In large ulcers it may be necessary to use two flaps, one from each buttock, with the base of the flap placed higher on one side than the other (Fig. 3). As a general rule, it is wise to try to avoid having the flaps meet in the midline, although it is not always possible to avoid this and it does not invariably lead to an unsatisfactory result.

TABLE I

| Patient | Site and Size | Culture | Operation | Postoperative Course | Time of Healing |
|---|---|---|---|---|---|
| 1. Charles F. Lt. USNR | Sacral: 3 x 6 cm. | *Hemolytic Streptococci* | Sliding flap 6/15/45 | Small hematoma leaving 2 x 3-cm. opening, which drew together after granulation | 3 mos. |
| 2. William W. BM 2/c | 1. Sacral: 4 x 6 cm. | *B. coli* and *Staph. aureus* | Sliding flap 7/16/45 | Primary healing, but partial reopening 5 wks. later, following urinary sepsis | Immediate |
| | 2. R. hip: 3 cm. | | Simple closure 9/26/45 | Primary healing | Immediate |
| 3. Alan W. AMM 3/c | 1. Sacral: 8 cm. | *B. pyocyaneus* and *B. coli* | Sliding flap 7/20/45 | Primary healing except for 2-cm. area of suture separation | 1 mo. |
| | 2. Midback: 8 x 19 cm. | | Simple closure 8/28/45 | Primary healing | Immediate |
| 4. Walter M. Pvt. | 1. Sacral: 5 cm. | *B. coli* | Simple closure 9/6/45 | Primary healing | Immediate |
| | 2. Hip: 6 x 9 cm. | *Anaerobic Streptococci* | Sliding flap 10/15/45 | Primary healing except for 2 x 3-cm. separation which required secondary suture | 3 mos. |
| | 3. Post. sup. spine: 5 cm. | | Simple closure 1/16/46 | Primary healing | Immediate |
| 5. John C. Lt. USMCR | 1. L. hip: 5 x 8 cm. | *B. proteus, B. coli, hemolytic Staph. albus* and *anaerobic Strep.* | Sliding flap 10/5/45 | Primary healing, but recurrence after second operation | Immediate |
| | 2. R. hip: 3 x 5 cm. | | Simple closure 1/4/46 | Acute infection and ultimate separation of flaps | Failure |
| 6. George A. Pvt. | Sacral: 3 x 4 cm. | *Staph. albus* | Simple closure 10/22/45 | Small central separation of incision, which healed by granulation and contraction | 5 wks. |
| 7. Lionel LaF. Pvt. | Sacral: 12 cm. | *Staph. aureus* and *B. coli* | Bilateral sliding flaps 10/24/45 | Partial necrosis and separation of flaps | |
| | | | Secondary closure 11/30/45 | Successful approximation, with delayed healing | 2.5 mos. |
| 8. James S. S 1/c | Ischial tuberosity: 4 cm. | *B. coli* and *anaerobic Strep.* | Simple closure 11/26/45 | Slight separation and delayed healing of central third of flap due to hematoma. Small secondary breakdown after sitting on unpadded seat | 2 wks. |
| 9. Theodore K. S 2/c | Post sup. spine: 3 cm. | *Hemolytic Strep.* and *B. proteus* | Simple closure 1/11/46 | Separation of central third of incision because of hematoma | Firm healing in 2 wks. |

The best donor site for flaps to cover ulcers over the anterior superior spine is the skin just lateral to the spine on the side of the thigh, and to cover ulcers over the greater trochanter we have slid a flap from the lateral surface of the buttock (Fig. 5). Ulcers in these regions are often relatively small and the closure of the donor site is then a simple matter.

Absolute hemostasis and the avoidance of hematoma formation is essential to primary healing, and the greatest of care is required to accomplish this. A hematoma will always prevent primary union (Fig. 4) and the time taken to obtain hemostasis is well spent. The liberal application of fibrin foam soaked in thrombin to any points which show a tendency to ooze should help prevent this complication.

We have used No. 00 plain catgut sutures for the subcutaneous tissue and silk for the skin. The suture lines are reinforced by sutures of fine stainless steel wire in mattress fashion, tied over small disks of roentgen-ray film to prevent cutting into the skin (Fig. 2D and 3A). The dressing is composed of several layers of gauze, over which mechanic's cotton waste is placed and the entire dressing held firmly in place by elastic adhesive strapping for firm, even pressure.

After operation the patient with a plastic repair over the sacrum is kept on his face or side to keep the weight of his body off the flap and he is not permitted to lie on his back for 14 days. Penicillin is given intramuscularly in doses of 15,000 Oxford units at three-hour intervals over this period. In order to prevent early soiling of the surgical dressing after plastic closure of decubitus ulcers in the region of the buttocks, the patient should be fed a low residue-constipating diet and liberal doses of paregoric for the first week, followed by an enema just before the first postoperative dressing. This is normally done on the 6th to 7th day and most of the skin sutures are removed at that time (Fig. 2D). The wire tension sutures are removed on the 12th or 14th day. If there is evidence of hematoma formation, the clot is evacuated and the cavity packed with gauze soaked in a solution of penicillin. Secondary suture to obliterate the cavity may be undertaken later if deemed necessary (Fig. 3B and C).

## RESULTS

The results of this method of radical one-stage excision and closure of various types of decubitus lesions in paraplegic patients are set forth in Table I and the accompanying photographs. Study of these data shows that primary healing took place after six of the 14 operations (Patients 2, 3, 4, 5; Figs. 1 and 6). Following six other operations (Patients 1, 3, 4, 6, 8, 9) there was primary healing of nearly the entire area, but a small portion of the cutaneous flaps, 1 to 2 cm. in extent, separated because of undue tension or an underlying hematoma (Figs. 2D and 4). Although this area remained free of visible infection in each instance, it required from a few weeks up to three months to heal by granulation and secondary ingrowth of epithelium. After the closure of the large trochanteric decubitus ulcer in Patient 4 (Fig. 5), it was necessary to close a residual 2-cm. superficial defect by a secondary plastic procedure. Even in these instances most of the patients were able to be up in a wheel chair within two weeks and the final result left little to be desired, as the area of the former lesion was covered with full-thickness, freely movable skin, with an underlying pad of fat.

Troublesome postoperative complications resulted in only two patients. A single instance of major postoperative sepsis occurred in Patient 5. Here, a 5 by 8-cm. decubitus ulcer over the left great trochanter had been previously excised and successfully healed by primary union. Following this the patient's general condition had deteriorated, due to an adhesive peritonitis, partial intestinal obstruction, and severe malnutrition. In addition to a huge sacral

bedsore, there were decubitus ulcers over both ischial tuberosities and a 3 by 5-cm. lesion over the great trochanter on the right side. On account of a complicating compound fracture of his humerus, it was impossible to make this patient lie in the prone position. We resolved to attempt to close the bedsore over the right hip, in spite of his obvious malnutrition, in the hope that he would then be able to spend more time in the lateral position and thereby take the weight off his sacrum and buttocks. This ulcerated area was excised and the edges drawn together on January 4, 1946. Four days later



A B C

FIG 4—Case 1: (A) Preoperative photograph of sacral bedsore, with outline of extent of excision and area in left buttock to be raised for sliding flap.

(B) Photograph taken two weeks later showing first intention union of all but small undermined area at site of hematoma.

(C) Photograph taken three months later. There is a thick pad of fat and the skin is not adherent to the sacrum.

there was a fever of 101.8°F., and the skin flaps were found to be undermined with pus, which contained *anaerobic Streptococci* and *B. proteus*. A few sutures were removed and the cavity irrigated at three-hourly intervals with penicillin solution (1,000 units per cubic centimeter), in addition to the routine intramuscular injection. His temperature returned to normal within 24 hours, but there was subsequent complete separation of the flap and failure to reduce the extent of the ulcerated area. Unfortunately, we were unable to obtain any streptomycin at this time.

The other postoperative complication, which occurred in Patient 7, was caused by undue tension and inadequate circulation of the transposed cutaneous flaps. Here, it was necessary to remove a large area of avascular scar surmounted by three indolent ulcers. This measured 12 cm. in diameter and covered most of the sacrum. To close such a large area it was necessary to

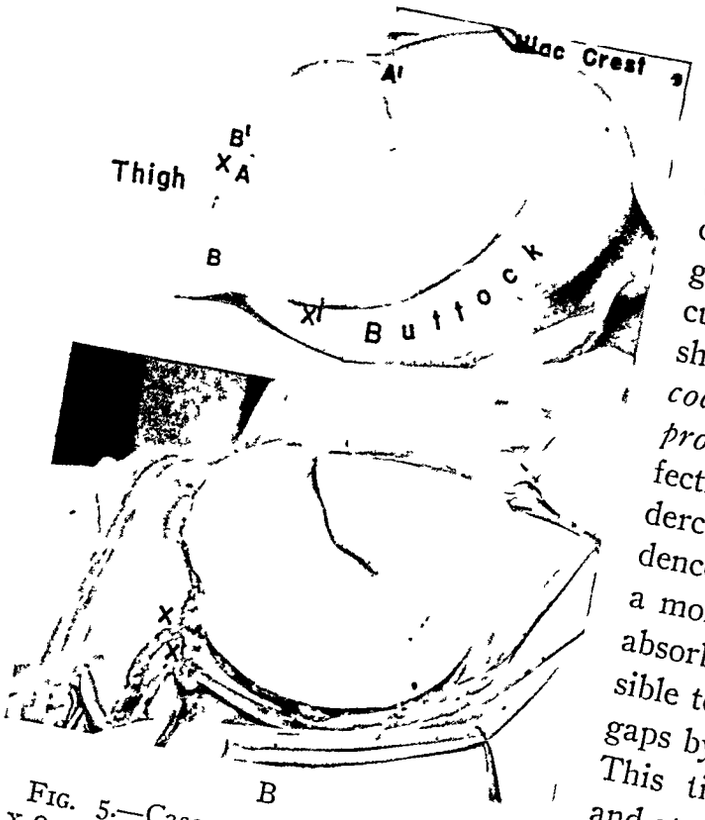



FIG. 5.—Case 4: (A) Photograph of 6 x 9-cm. trochanteric decubitus ulcer, with outline of flap to be raised. After excision of the ulcer and its scarred edges point A is to be rotated to A', B to B'. The resultant defect at the lower left-hand corner will be closed by undermining the thigh and buttock and approximating X to X'. (B) The flap has been rotated and area from which it was taken closed by subcutaneous suture with No. 00 plain catgut. Silk cutaneous and wire mattress stitches remain to be placed. Tension on skin edges was minimal, but there was a small separation in lower limb near the anus which required secondary closure.

elevate and swing in bilateral flaps.[1] The edges of these appeared slightly blanched as the postoperative dressing was applied. Within a week there was definite necrosis of the distal 2 to 3 cm. of both flaps (Fig. 3A), which gradually sloughed away. Although cultures from the sloughing areas showed a heavy growth of *Staphylococci, anaerobic Streptococci,* and *B. proteus,* there was no tendency for infection to spread into the widely undercut areas and almost no evidence of systemic absorption. Within a month the necrotic tissue had been absorbed (Fig. 3B) and it was possible to reapproximate the 3 to 4-cm. gaps by a secondary plastic operation. This time healing was satisfactory, and at the end of a month the sacrum was covered with a fair cushion of full-thickness skin and subcutaneous fat (Fig. 3C). If confronted by a similar situation in the future, where there is even a slight blanching of the flaps, we plan to resort to the "delayed-flap" method and complete the plastic at a second stage.

After the successful closure of decubitus lesions there is still the possibility that secondary ulceration may take place. Although well prepared plastic flaps appear to be just as resistant to pressure necrosis as other areas of intact skin, the facility with which insensitive skin can break down must always be borne in mind. Two of the five patients reported by White, Hudson, and Kennard[1] developed small secondary decubitus ulcers in the transposed flaps when they were forced to return to bed and lie on their backs because of late urinary sepsis. This unfortunate complication has occurred in Patients 2, 5, and 8 of the present series. In the first, the primary sacral closure had healed by first intention (Fig. 6), but 5 weeks later a severe ascending urinary infection, accompanied by a fever of 105°F. caused the distal 3 cm. of the transposed flap to break down and a new 3-cm. ulcer to form overnight over the right great trochanter. This was subsequently closed and healed *per primam,* but at eight months a 2 by 4-cm. superficial defect still remains over the

sacrum (approximately a third of the area of the original flap). The second case of recurrent ulceration occurred in Patient 5, mentioned above. Here, in desperation, we attempted to close a trochanteric ulcer in a severely undernourished patient because this unfortunate officer was unable to lie prone and had steadily increasing decubitus ulcers over his sacrum and both buttocks. If this 3 by 5-cm. ulcer could have been closed he would have been able to spend a large part of the time lying on either side. This ill-advised attempt on our part resulted not only in acute infection and breaking down of this plastic, as already stated above, but also in a partial breakdown of the beautifully healed area over the opposite hip, which had united *per primam* after an earlier closure. The third case of recurrent ulceration was only a partial breakdown of a successfully closed decubitus ulcer over the ischial tuberosity. This patient had been taken to a hockey game and sat for several hours on a poorly cushioned seat.



A B

FIG. 6.—Case 2: (A) Preoperative photograph of the sacral decubitus ulcer. (B) Primary union at end of two weeks.

The lesson to be derived from the first two discouraging instances of secondary ulceration after successful plastic closures is that the procedure should be undertaken only in reasonably well-nourished individuals who are past the stage of recurrent episodes of sepsis, either from the urinary tract or from other wounds. This state is far easier to attain in civilians, who never should become severely undernourished and in whom complications outside the urinary tract are relatively infrequent. Out of a group of 30 war-time paraplegic patients, five remain to date with decubitus ulcers which we have been unable to attempt to close. Three of these marines, on admission, were so undernourished and had so many and such large bedsores that it has been impossible to build them up to a state of positive nitrogen balance. In two others, persistent sepsis from other wounds has prevented reparative plastic

surgery to date. One of these men had a chronic empyema following a crushing injury to his chest and spine, the other a traumatic fecal fistula, osteomyelitis of the ilium, and retroperitoneal abscess. Both of these men are well on the road to recovery from their septic foci, and nearly ready for closure of their indolent pressure sores.

## SUMMARY AND CONCLUSIONS

1. With the protection of penicillin, decubitus ulcers can be resected and closed by primary suture. This permits rapid closure with full-thickness skin and early rehabilitation of patients with spinal paraplegia.

2. Adequate preliminary treatment is essential to combat anemia, hypoproteinemia, and avitaminosis. Bladder paralysis is treated by tidal irrigation; chemotherapy and surgical measures are used to clear-up sepsis in the urinary tract and the tissues surrounding the decubitus ulcer.

3. The ulcer is then débrided and plastic skin flaps swung in for primary closure. A compressive dressing is applied and penicillin is given intramuscularly during the healing period.

4. Surgical technic and end-results after closing 14 of these ulcers are described.

5. Experience proves that clean healing is the rule. Hematomas or undue tension result in small defects which heal cleanly but more slowly. Within 14 days many of these lesions have been firmly healed with well-padded movable skin covering the former defect. Troublesome postoperative complications have resulted in only two cases—necrosis and separation of the cutaneous flaps resulting from undue tension, and a single instance of frank sepsis in a malnourished patient.

6. Even after a pressure sore has been excised and successfully covered with full-thickness skin and subcutaneous tissue, it can break down again during periods of inadequate care or severe infection.

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# THE PRIMARY CLOSURE OF DECUBITUS ULCERS*

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BEDSORES are caused by the interruption of the blood supply to the skin by pressure. Necrosis occurs when this local anemia is continuous and persists for a sufficient length of time. Very little quantitative data can be found in the literature upon the amount of pressure required to produce complete anemia of the skin and the duration of the anemia required to produce necrosis. The War Department Technical Bulletin (TB MED 162) on the care of patients with spinal cord injuries reads: "It is believed that maintained pressure for three to four hours may be sufficient to produce skin necrosis." The evidence for this statement is presumably based upon clinical observation.

Trumble,[25] in 1930, made an attempt to obtain quantitative data on the duration and amount of pressure which could be tolerated by normal skin. He studied skin tolerance for pressure and pressure sores, pointing out that the duration and amount of pressure are the important factors in the production of decubitus ulcers. He conjectured that skin tolerance for prolonged continuous pressure was probably well below 120 mm. Hg., or 2.3 lbs. per square inch. The problem was studied by applying a small rubber bag to the dorsum of the foot in two subjects, one a boy 12 years old and one a man. Constriction was avoided by bandaging over a plaster slab applied to the sole of the foot. The rubber bag was connected by a tube to a funnel of water which could be raised and lowered. He found that the boy could tolerate a pressure of 39 inches of water, or 73 mm. Hg., for days without experiencing pain. This amounts to a pressure of about 1.5 lbs. per square inch. The pressure the man could tolerate was slightly lower, about 1.25 lbs. per square inch. No further details concerning these observations are given. They obviously require confirmation and elaboration.

The surface area of a man five feet eight inches tall, weighing 150 lbs. is about 2,790 square inches. Trumble[25] points out that if only one-fifth of this area were available for weight-bearing in the recumbent position and the pressure were evenly distributed, it would amount to less than one-third of a pound per square inch. However, the weight of the body in reality falls heavily on certain points the combined areas of which are very small. These

* Report based on experience with paraplegic patients in an Army General Hospital in the United States.

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points occur over parts where the skeleton is near the skin surface, *i.e.*, the heels, the sacrum, the posterior superior iliac spines, the spines of the vertebrae and the scapulae, *etc.* The skin in these regions bears the weight not only of the part directly above it but also of other parts which are not adequately supported. The bulky soft parts, the buttocks and calves, deform with pressure and evade the responsibility of carrying the weight of the tissues directly above them.

The evaluation of the neurogenic trophic factor in decubutis ulcers of paralyzed patients has plagued the literature since the time of Charcot,[4] despite the fact that a number of his eminent contemporaries disagreed with him. Brown-Sequard,[3] in 1853, published some classic observations bearing on this question: "On guinea-pigs, upon which the spinal cord was cut in the dorsal region, and on pigeons, upon which the spinal cord was destroyed from the fifth costal vertebra to its termination, I have found that no ulceration appeared when I took care to prevent any part of their bodies from being in a continued state of compression, and of washing them many times a day to remove the urine and feces. In cases where an ulceration had been produced, I have succeeded in curing it by washing and preventing compression. I have found that in animals having the spinal cord cut across every kind of wounds or burns were cured as quickly as in healthy animals. Therefore, the ulcerations which appear in cases of paraplegia do not exist directly in consequence of the palsy; they can be avoided and in many cases they can be cured."

Sir James Paget,[22] writing at the same time as Charcot, was well aware of the essential cause of bedsores: "Bedsores may be defined as the sloughing and mortification or death of a part produced by pressure . . . In bedsores the pressure is continual, the blood is driven away, nourishment ceases, and death of the part takes place. . . . If there is the slightest movement from one side to the other, bedsores may be averted . . . In case of those whose lower limbs may be paralyzed, there can be no motion whatever, and so they are liable to bedsores." In 1889, Cohnheim[5] in discussing the subject of bedsores, succinctly disposed of the question of trophic nerves in the following manner: "After all that has been said, you will grant, I think, that the evidence brought forward up to the present is too imperfect to admit of our inferring therefrom either the existence of trophic nerves or the importance of trophic nervous influence for the nutrition of the organs and tissues in general."

Despite the evidence of these authorities, Charcot's influence persisted. Freeman,[12] in 1907, writing in Keen's System of Surgery, remarked that Charcot attempted to explain the rapid spread of decubitus ulcers associated with spinal cord injuries by assuming the "existence of certain trophic centers governing nutrition, damage to which results in 'neurotic necrosis' when aided by local pressure." However, he further states that: "In considering the causation of bedsores, it is customary to keep prominently in view their division into ordinary decubitus and that appearing in connection with nervous lesions, although it is doubtful if any real difference exists between them."

Munro[21] is the most recent proponent of the importance of nervous in-

fluences in decubitus ulcers of paralyzed patients. He believes that "an adequate supply of blood to the skin depends on the integrity of two reflex arcs, which must include at least the spinal cord." He states that bedsores which exist in connection with spinal cord injuries start as pressure sores "but develop more viciously and more widely because of the deleterious effect of spinal shock on the local cutaneous vascular reflexes." The clinical evidence in support of this explanation is based on comparing the incidence of bedsores and the hospital mortality in patients with thoracolumbar cord injuries and in those with cervical cord and cauda equina injuries. The conclusions drawn from this evidence do not appear to us to be warranted.

Local pressure on the skin and the influence of malnutrition afford an adequate explanation for the appearance and rapid spread of decubitus ulcers in paralyzed patients without invoking an hypothetic factor of nervous reflexes or neurogenic trophic disturbances. Pressure on the skin of the paralyzed patient is apt to be more continuous because, awake or asleep, he does not change his position frequently as does a normal individual. Furthermore, because of the absence of pain sensations from the skin which has been pressed upon, the normal stimulus to such movement does not exist. We do not believe that any neurogenic trophic changes occur in the anesthetic skin of patients with paraplegia. The only obvious change in the skin is the dryness due to the usual, but not invariable, absence of sympathetic activity.

Reactive hyperemia is the most important protective mechanism in the body to prevent skin necrosis following a period of anemia. The reaction has long been known[17] but the most comprehensive and authoritative work on the subject has been done by Sir Thomas Lewis.[16] Cope[6] has emphasized the importance of this reaction in relation to bedsores.

We shall discuss here the phenomenon only in relation to the skin. The reaction consists of a flushing with blood of skin previously deprived of its blood supply. Absence of the blood supply for five seconds will produce a perceptible reaction. The duration of the flush is related directly to the length of the interruption of the blood flow, up to a period of an hour or more. Roughly, the reaction lasts one-half to three-quarters of the time of vascular occlusion, and "is thought to result from the accumulation in the extravascular tissue fluids of slowly diffusible substances, the products of metabolism during the period of circulatory disturbance."[16] Lewis has conclusively shown that the reaction is a local one and is independent of both the central nervous system and local reflexes.

Thus, the most important feature of the prophylactic and active treatment of decubitus ulcers must be the avoidance of prolonged periods of pressure upon the skin, pressure which is sufficient to produce local anemia. The simplest method of accomplishing this is to turn the patient every two hours. When a number of paraplegic patients are being cared for, this requires the constant vigilance of a large staff of nurses, orderlies and assistants. The few decubitus ulcers which developed while patients were under

our supervision always followed blanching pressure upon an area of skin for longer than two hours.

There is another way of attacking the problem. Trumble[25] has pointed out that there are two quite different methods of distributing the weight of the body so as to avoid excessive pressure on the areas of skin overlying bone. One is by providing a very soft bed and the other is by employing a very hard one. A prototype of the first is the "water-bed," which consists of a rubber bag mattress partially full of water which allows the body to sink into it and so requires the bulky soft parts to support their share of the weight of the body. There are many variations of this type of bed, such as the air mattress, the foam rubber mattress[23] and the sawdust bed.[13] The hard bed also equalizes pressure by an entirely different method. It consists of an accurately fitted plaster of paris shell. For a patient recumbent in the supine position the plaster shell extends from the gluteal folds and may or may not include the neck and head above. Laterally, it extends half way around the body on either side. A patient may lie in such a plaster shell for months,[6] without changing position and the skin will remain intact and healthy. In making such a plaster shell Trumble emphasizes the importance of placing one-quarter-inch wool pads over the bony prominences. These wool pads are later removed. The plaster shell is made with the patient in the prone position and in this position the soft parts sag away from the bony prominences of the back. The placing of the pads in making the plaster shell compensates for this when the patient is turned to the supine position.

One or another of the above methods, *i.e.*, frequent change of position, a soft bed which distributes the weight of the body over a large area of skin, or a hard bed which conforms to the contours of the body, and so accomplishes the same thing, must always be employed in handling the paralyzed patient.

The state of nutrition of the patient is a factor of great importance in the treatment of decubitus ulcers. Adequate supplies of protein[24] and vitamins[15, 19] have been shown to be essential to wound healing in recent years. Freeman,[12] as early as 1907, observed that in rare instances of severe malnutrition, areas of skin necrosis may appear where the pressure upon the skin "is slight or transient, such as is produced by the mere weight of the bed clothes or the hand lying upon the abdomen. In cases of extreme emaciation certain bones, particularly the anterior superior spinous processes of the ilium, may protrude through the overstretched and atrophic skin without the aid of external pressure at all." Such instances are, of course, extreme but serve to emphasize the nutritional factor in the production of decubitus ulcers. Recently Mulholland, *et al.*[20] found that in 35 random cases of bedsores the plasma protein concentration in all of them was below 6.4 Gm. per cent. Healing or marked improvement in the ulcers occurred in eight patients who were given a high protein diet. Thus, it becomes of the utmost importance to insure that these patients receive a high protein diet and adequate supplies of vitamins.

With a good general state of nutrition and the avoidance of local pressure, small superficial decubitus ulcers will eventually heal. Often the process requires months during which time there is a continuous loss of protein-containing fluid from the granulating surface which further complicates the nutritional problem. Large ulcers and those with deep pockets often fail to heal even after months of the best conservative therapy. The similarity of the problem to that following a burn with full-thickness skin loss is obvious. The early employment of skin grafting very naturally suggests itself as a simple and adequate method of promoting healing of these ulcers. Consequently, in many Army hospitals in this country skin grafting represented the first surgical attack upon decubitus ulcers. Small deep[10] and split-thickness[2] skin grafts were the types which we employed. We were generally successful with small deep grafts, and believe they are of definite value in the surgical treatment of these ulcers. However, we, and others, have not been satisfied with the results of either spontaneous healing or free skin grafts for the following reasons:

The end-result of spontaneous healing is a dense scar overlying a bony prominence, covered with a thin sheet of squamous epithelium adherent to the underlying scar. This area is liable to break down from slight pressure, and obviously such a patient is far more likely to have a recurrent decubitus ulcer than a patient with full-thickness skin and subcutaneous fat overlying a bony pressure point. The same criticism applies to the results of skin grafting. An avascular scar is still present, there is no subcutaneous tissue, and the skin is not full-thickness.

It was with these points in mind that a decision was made to cover the bony pressure points with subcutaneous fat and full-thickness skin by excising the ulcer and closing the defect by rotating and advancing skin flaps from the immediate vicinity of the ulcer. The advantages of using adjacent skin in preference to skin flaps or tubes from a distant site are several. The closure is immediate, it is done in one stage, and does not require the use of plaster to immobilize the parts while the flap or tube is becoming vascularized at its transplanted site. All these considerations are important in patients with paraplegia.

We have been unable to discover in the literature prior to 1945 any reports on the excision and primary closure of decubitus ulcers. During 1945 a few surgeons in Army hospitals in the zone of the interior have reported at Service Command Conferences small series of cases in which bedsores were treated by skin grafting or some form of plastic closure. In February, 1945, Lamon and Alexander[11] reported the successful excision and primary closure of three decubitus ulcers in one patient. The ulcers were apparently small and were excised by an elliptical incision and a linear closure was performed after undermining the skin. In January, 1946, Croce, Schullinger and Shearer[9] reported their results in eight sacral decubitus ulcers treated by excision and primary closure. Their procedure is fundamentally similar to the procedure we have employed — excision of the ulcer and surrounding

scar in one piece, the development of adjacent skin flaps and primary closure. The only essential difference between their technic and ours is that we have usually employed only two broad flaps and have avoided angles. Closure has been achieved by rotating these broad flaps rather than by advancement of multiple small flaps.

The principles which most of us have employed were well illustrated and discussed by Davis[11] in 1938, in an article on the "Operative Treatment of Scars following Bedsores." The only difference is that the decubitus ulcers in his cases were healed by a thin layer of epithelium prior to the operative procedure.

## PREOPERATIVE CONSIDERATIONS

The patient paralyzed from a spinal cord injury frequently presents a difficult nutritional problem. Because of their poor appetite it was often difficult to persuade them to take sufficient nutrition by mouth to maintain a

TABLE I

PLASMA ASCORBIC ACID LEVEL

| | Variation Mg. Per Cent | Average Mg. Per Cent |
|---|---|---|
| 8 patients with poor appetites | 0.19—0.39 | 0.29 |
| 18 patients with good appetites | 0.33—0.78 | 0.57 |
| 11 normal controls | 0.65—1.42 | 0.96 |

positive nitrogen balance or to gain weight. In accordance with Army directives, paraplegic patients were given at least 3,500 calories a day. To accomplish this the food had to be inviting and well prepared. Extra nourishment was given between meals and at night. The daily protein intake was at least 125 Gm. a day. When this could not be accomplished by mouth the diet was supplemented by intravenous protein digests. In addition to the vitamins in the diet, supplemental vitamins were usually administered.

It was desirable that the levels of serum protein and hemoglobin should be as close to normal as possible before operation. When indicated, patients were treated vigorously with repeated blood transfusions, plasma infusion and intravenous protein digests or amino-acids before and after operation. In the first 27 patients operated upon, the average hemoglobin before operation was 13.7 Gm. per cent (varying between 10.9 and 15.9 Gm. per cent). The serum protein levels prior to operation averaged 6.4 Gm. per cent (varying between 5.8 and 7.2 Gm. per cent). However, as Abbott and Mellors[1] have shown, the hematocrit and plasma protein may be near normal values even when a relatively large deficit exists in the total number of red blood cells or the quantity of circulating plasma protein. Consequently, in addition to normal levels of hemoglobin and plasma protein, we also considered a good appetite and a steady gain in weight as desirable before operation.

The plasma vitamin C level was determined in 26 patients with paraplegia (Table I.). It can be seen that those patients who had poor appetites had low levels of ascorbic acid in their plasma, approximately one-half that found in the patients with good appetites. Crandon and Lund[7, 8] have shown, in a classical experiment on a human subject with a pure vitamin C deficiency, that a wound will heal adequately even though the plasma ascorbic acid has been zero for as long as 44 days. However, in this human subject there were no other vitamin deficiencies. In actual practice such a state of affairs is probably never found, and we believe that a plasma ascorbic acid level below 0.5 mg. per cent indicates a low saturation of the body with not only vitamin C but also other vitamins. Hence, in all our patients who were eating poorly, supplemental daily doses of vitamin C and other vitamins were given.

It is preferable, of course, to have a clean, healthy looking ulcer with red granulations surrounded by a margin of growing epithelium. Under these circumstances the patient's nutrition is probably good and there is evidence that the essential materials for wound healing are present. However, we have successfully operated upon patients in whom the ulcer bed was covered with dirty gray unhealthy looking granulations, and where there was no epithelial proliferation at the margins of the ulcer. Undermining of the margins of the ulcer and the presence of deep pockets are not a contraindication to operative closure, though they increase the technical difficulties.

All sloughing tissue should be excised before operation in order to diminish the surface infection and to have better visualization of the extent of the ulcer. The following organisms were cultured from the surface of the ulcers: *Bacillus pyocyaneous; Escherichia coli; Bacillus proteus; hemolytic Staphylococcus aureus; nonhemolytic Staphylococcus aureus; Staphylococcus albus; beta-hemolytic Streptococcus.* No special attention was paid to the bacterial flora present. Only cellulitis or inadequately drained pockets of pus were considered to contraindicate operation.

## TECHNIC

If there was an indwelling catheter, either urethral or suprapubic, it was left open to drain into a bottle during the course of the operation. In one instance, through an oversight, the catheter remained clamped and an upper urinary tract infection resulted. In most cases no anesthesia was required. In a few patients with low injuries of the spinal cord local infiltration with novocaine was necessary to block off painful impulses from the upper portion of the operative area.

The entire bed of the ulcer including undermined margins and pockets together with the surrounding skin were thoroughly washed with soap and water. The skin and ulcer were then cleansed with ether and painted with tincture of mercresin. Two semilunar incisions encircling the ulcer were made through the normal skin, just beyond the thin epithelium covering the scarred borders of the ulcer. The entire ulcer, with its pockets and its base,

was then removed in one piece. Sometimes the base had to be actually shaved off the sacrum. During the process the gloved hands of the operator and assistants never touched the surface of the ulcer. All instruments which had come in contact with the skin or the surface of the ulcer were discarded.

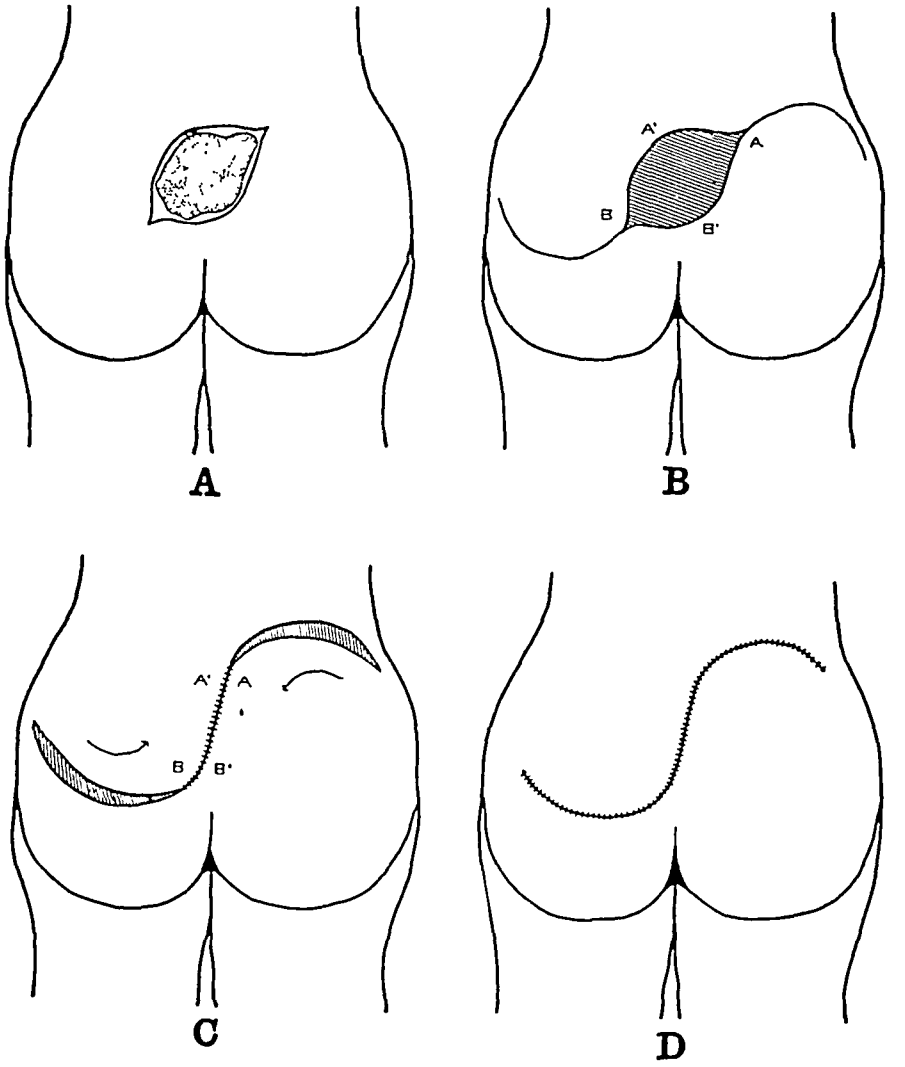



FIG. 1.—Drawings illustrating steps in the operation.

(A) The stippled area represents the ulcer and the heavy lines the two semilunar incisions about the ulcer.

(B) The shaded area represents the raw surface after excision of the ulcer. The curved extensions of the incision are shown.

(C) The skin flaps have been mobilized, rotated toward the midline, and partially sutured.

(D) Suturing completed. Note broad bases of skin flaps and absence of sharp angles.

From then on the operation was carried out as though it were in a completely clean field.

Small ulcers, 1 to 2 cm. in diameter, could frequently be excised between two semilunar incisions and the resulting defect closed by mobilizing the skin margins and suturing them together in a straight line. This method cannot be used to close large ulcers. In these cases long curved extensions of the

incision were made on each side beginning where the tips of the original semilunar incisions met (Fig. 1 A,B,C,D,). The concavity of the curve was reversed on opposite sides. The incision was carried down through the subcutaneous tissue to the fascia overlying the gluteus maximus muscles in

FIG. 2



FIG. 4





FIG. 3



FIG. 5

FIG. 2.—Sacral decubitus ulcer on H. M. at the time of operation, July 9, 1945. The ulcer measured 7x7.5 cm., with a border on the left which was undermined for 1.5 cm. and a thin scar on the right 1 cm. in width.

FIG. 3.—The entire ulcer with surrounding scar and undermined edge has been excised between two semilunar incisions, extending from above on the right to below on the left. Curved extensions of the incision have been made to develop flaps for rotation. The concavity faces upward on the left and downward on the right.

FIG. 4.—The skin flaps are retracted to show the extent of undermining. Note the broad bases of the skin flaps. The plane of separation is between the subcutaneous tissue and the fascia overlying the gluteus maximus muscles.

FIG. 5.—The flaps have been rotated, as shown in Fig. 1-C, and sutured together with buried stitches of fine cotton in the subcutaneous tissues and silk sutures in the skin. Note the absence of any sharp angles. No drains were used in this case. The wound healed *per primam*, and there has been no recurrence of the decubitus ulcer.

the back in sacral decubiti, or the fascia lata in the thighs in ulcers overlying the femoral trochanters. The skin and subcutaneous tissue flaps were then widely mobilized, the plane of cleavage being between the fascia and the fat. The extent of undermining in a moderate-sized ulcer is shown in Figure 4. It is important always to insure that the flaps have a broad base. Once

serious difficulty was encountered with the blood supply of a flap because of failure to adhere to this principle (Fig. 11).

After mobilization the flaps were rotated and drawn toward one another. The mobilization should be extensive enough so that the flaps can be sutured together with a minimum of tension. The rotation of the flaps is illustrated in Figure 1 C, and the suture line after closure is shown in Fig. 1 D and Fig. 5. This type of procedure was used in the majority of our cases. Some ir-

FIG. 6



FIG. 8

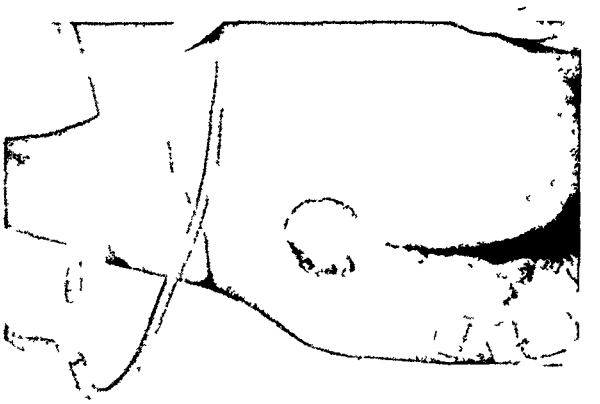






FIG. 7

FIG. 9

FIG. 6.—The result four weeks after operative closure of a sacral decubitus ulcer in S. by similar technic.

FIG. 7.—The result in R. six months after operation in one of the largest sacral decubitus ulcers operated upon. The transverse diameter of this ulcer was 14 cm. and the vertical diameter was 8 cm.

FIG 8.—Decubitus ulcer in L. six months before operation. At time of operation, August, 1945, the ulcer measured 7 cm. in transverse diameter and 3.5 cm. vertically. There was a 3-cm. scar extending down to the gluteal fold and 1.5-cm. undermining on the right and 5-cm undermining on the left.

FIG 9.—The result five months after operative closure in L. The scar of the incision on the right can be seen as a thin line extending laterally just below the right posterior superior iliac spine.

regular ulcers (Fig. 10) required a modified technic but throughout our series two main principles were observed whenever possible. Skin flaps were made with bases that were very broad in relation to the length of the flaps. Skin margins were cut smoothly in curves avoiding corners and sharp angles. The technic described here is thought to be safer than that described by

Croce, *et al.*[9] They advanced a number of small, long, narrow flaps with corners at the free extremities instead of using broad curved flaps which avoid angles.

Two methods were used for hemostasis. In approximately three-fourths of the operations fine cotton (No. 120) was used for ties. In the remaining one-quarter the bleeding points were coagulated with electric current. There appeared to be little difference between the two methods in the healing of the wounds. Toward the end of our series, electrocoagulation was used more frequently because it increased the operative speed, a consideration of some importance in these patients. It was obviously dangerous for the patients to lie prone on the operating table longer than two hours, because of the possibility of developing decubitus ulcers over the anterior iliac spines.

Before suturing the flaps together at the conclusion of the operation the entire wound was thoroughly irrigated with sterile warm salt solution. Suturing was then begun in the central portion of the wound (Fig. 1 C). A series of interrupted stitches of No. 80 cotton were placed at very close intervals in the subcutaneous tissues close to the skin. The stitches were so placed that, when tied, the knots would lie in the deeper portion of the wound. None were tied until the entire row was in place. Traction was then made on all the threads drawing the wound together while each stitch was tied. This distributed the tension and prevented the cutting-through or breaking of the individual stitch. Cotton was invariably used for buried suture material. Only in rare instances was thread heavier than No. 80 required for sutures. Number 120 thread was used for ties. In our later cases cotton was also used for skin sutures instead of silk because it appeared to produce less reaction.[18]

Because of the extensive dissection required to close large ulcers, one or two rubber tissue drains were frequently placed in the angles of the wound as a precaution against the accumulation of serum. These drains were removed in 24 or 48 hours. A dressing of fluffed gauze and cotton waste was applied at the close of the operation and held firmly in place with transverse strips of elastic adhesive tape. Before applying adhesive plaster the skin was carefully cleansed with ether and painted with compound tincture of benzoin. This proved of value in preventing excoriation and pustule formation under the adhesive.

Postoperatively, it was inadvisable to allow the patient to remain in the prone position for any great length of time because of the danger of developing decubitus ulcers over the anterior superior iliac spines. The patient could lie on his sides for short intervals of time but, here too, the danger of skin necrosis over the trochanters of the femurs was always present. Consequently after the first 24 or 48 hours the patient was permitted to lie in a supine position for as long as two hours. In recent cases the Stryker frame has been used and the patient turned from prone to supine position and back again regularly every two hours.

Intramuscular penicillin was administered to all patients starting the

morning of operation and continuing during the postoperative course until it was evident that the wound was healing properly without infection. In a few of the earlier operations sulfanilamide crystals were lightly dusted into the wound or a solution of penicillin was introduced before closure. In all the later cases the local use of drugs was abandoned. There was no increase in the incidence of infection in these cases. Of more importance in the primary healing of the wound is a meticulous operative technic, with the avoidance of tension and contamination, and the use of fine cotton for suture material.

Sutures were removed usually on the eighth day, but sometimes as early as the seventh or as late as the 11th postoperative day, depending upon the appearance of the wound, the degree of tension, and whether the sutures were cutting through the skin. A dressing was kept on the wound until it was soundly healed, moderately firm pressure being maintained by means of elastic adhesive.

TABLE II

RESULTS WITH EXCISION AND PRIMARY CLOSURE

| | |
|---|---|
| Healed primarily | 44 |
| Healed in four weeks | 6 |
| Healed in eight weeks | 4 |
| Improved | 5 |
| Failures | 5 |
| Death, eighth day | 1 |
| Total | 65 |

Sometimes, after the wound had healed collections of serum occurred beneath the skin. These were usually treated successfully by one or more aspirations with a needle and the continued application of a pressure dressing. Occasionally penicillin solution was injected through the needle after the aspiration of serum. In a few instances cotton sutures have been extruded from a wound several weeks after it appeared to be soundly healed.

## RESULTS

Table II summarizes the results obtained in the operative closure of 65 ulcers in 43 patients. Twenty-nine were sacral ulcers and 26 were ulcers overlying the femoral trochanters. The remaining ten ulcers had a miscellaneous distribution, including three ulcers over the tuberosities of the ischium, a result of sitting too long in a wheel chair. Primary healing occurred in 44 ulcers, or 68 per cent. If the first four categories of Table II are grouped together one might characterize 90 per cent of the operative results as satisfactory.

In the six instances in which the wounds were healed in four weeks the delay was caused in four of them by a slight separation of the wound edges where there was the greatest tension. In the fifth case there was some superficial infection around a skin suture and in the sixth case an hematoma formed which had to be evacuated.

In the four cases which were healed in eight weeks, one had sero-sanguineous drainage which later became purulent before it finally cleared up. In two there was some separation of the skin edges. Both wounds were

FIG. 10



FIG. 12

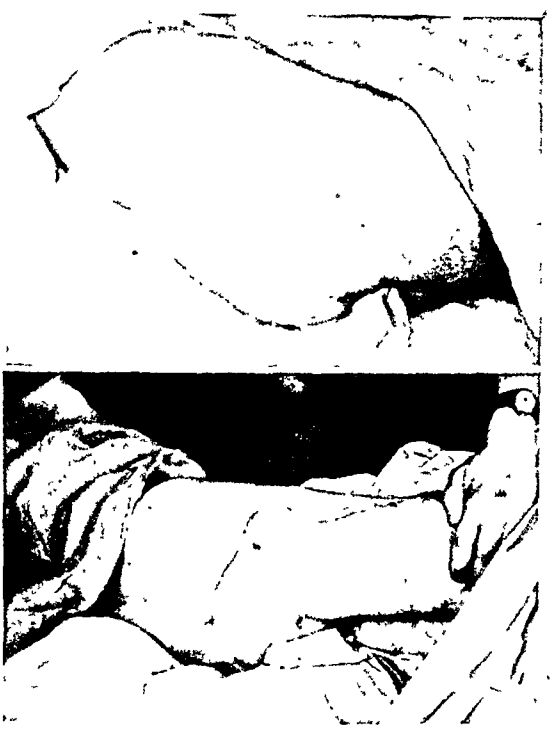


FIG. 11

FIG. 13

FIG. 10.—Sacral decubitus ulcer in C., with two typical small ulcers over the posterior superior iliac spines six months before operation. At the time of operation a large portion of the granulating area was covered with a thin layer of epithelium which broke down readily with slight trauma.

FIG. 11.—The end-result in C. five months after operation. This result was classified as a failure. The flap on the left side was undermined too extensively for the width of its base and there was sloughing of the margins of the flap in two areas, as can be seen in the photograph. The scar of the lower portion of the left-hand flap is partially obscured by the sheet. There was also some sloughing of the skin margins overlying the right posterior superior iliac spine. The wound has healed with the aid of small deep skin grafts.

FIG. 12.—The result of closure of the decubitus ulcer on the right hip in J. M. four months after operation. The ulcer measured 4x3.5 cm. and there was a 2-cm. undermining beneath the anterior and superior border of the ulcer. The usual curved incisions were made and skin flaps rotated to close the defect after excision of the ulcer. The wound healed *per primam*.

FIG. 13.—The result two months after excision of a decubitus ulcer over the right hip in E. The ulcer was long and narrow and extended from the greater trochanter of the femur down over the shaft. The length of the ulcer necessitated some modification of the usual curved flaps.

completely healed in eight weeks, one with the aid of small deep grafts. In the fourth instance the ulcer was extremely dirty and before operation showed no sign of healing. There was mild infection and some drainage, but the wound was completely healed in eight weeks.

Five results are classified as improved. In three cases there was some separation of the skin edges with persistent small ulcerations at the end of

eight weeks. In another a slightly larger defect healed with the aid of small deep grafts. In the fifth case an ulcer over the right hip was operated upon and the skin sutures were removed by mistake on the fifth day, with some separation of the wound edges. Ten weeks later there was a small persistent ulceration in the central portion of the incision. Three months after the first operation the patient was reoperated upon, with primary healing of the wound.

Five operations are classified as failures, and one death occurred on the eighth postoperative day. The death was from pneumonia associated with a severe urinary tract infection. At the time of death on the eighth day, the wound was perfectly clean and appeared to have healed *per primam*. Three of the five failures were due to infection with complete breakdown of the wound. In the fourth case there was too much tension on the suture line. The sutures cut through and there was separation and gaping of the wound. The fifth case is illustrated in Figures 10 and 11. There was a large raw area to be closed after excision of the ulcer and the incision on the left side was carried very far laterally in a curved fashion. The left limb of the "Y" defect after excision of the ulcer resulted in a dangerously narrow base to the flap which was unusually long. At the time of closure the skin margins were cyanotic and later sloughed. The wound eventually healed, with the aid of small deep grafts.

## SUMMARY AND CONCLUSIONS

1. Bedsores are due to pressure on the skin of sufficient magnitude to interrupt the blood supply. This ischemia, when continuous and of sufficient duration, produces necrosis.

2. The term "trophic nerve" should be abandoned. In our opinion, no evidence has been produced to show that an adequate blood supply to the skin, or its nutrition, is dependent upon an intact nerve supply. Our operative experiences confirm the original observations of Brown-Sequard.

3. Malnutrition is a factor in the production of bedsores and delays their healing.

4. The surgical problem presented by a large decubitus ulcer is similar in many respects to a third-degree burn with full-thickness skin loss.

5. The end-results of spontaneous healing and skin grafting are unsatisfactory because they do not provide full-thickness skin and subcutaneous tissue over bony prominences.

6. A method of operative closure of decubitus ulcers has been described. The method involves: (a) Complete excision of the ulcer, its margin and all pockets without contamination of the wound; (b) the formation of skin flaps in the immediate vicinity with curved borders and broad bases; (c) the rotation and advancement of these flaps to cover the skin defect without tension; and, finally, (d) the use of very fine cotton thread for suture material.

7. Sixty-five ulcers were operated upon by this method in 43 patients. Primary healing took place in 44 operations, or 68 per cent. The results could be regarded as satisfactory in 59 operations, or 90 per cent.

8. Complete excision and immediate plastic closure is the best method of treating bedsores in young patients with paraplegia.

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DISCUSSION.—DR. CHARLES C. LUND, Boston, Mass.: Although I have had no experience in the care of paraplegia, the problems of bedsores are comparable to the problems in the chronic stage of severe burns, and the experience from the use of high protein diets in burns should be useful in the care of patients with paraplegia. The first principle of diet is to get as much in by mouth as possible. Intravenous protein and glucose should be used only as supplementary diets in clinical work. Our experience has led us to believe that any fat in the diet of these patients causes distress, distension and diarrhea; therefore, we take all the fat out of the diet.

For our most severe patients we now use a diet containing 50 per cent carbohydrate and 50 per cent protein with very high calories. If an attempt is made to give such a diet with ordinary food, poor appetite usually will lead to the patient's picking the wrong items from a tray. Therefore, we concentrate on preparing a "burn drink" which we insist that the patient take. If this is taken we then do not worry how much solid food the patient eats. This diet is based on skim-milk which is skimmed in a separator, to which is added 10 per cent by weight of skim-milk powder, and 5 per cent by weight of Amigen powder, plus 1 per cent by volume of Valentine's liver extract. Such a mixture made on the basis of three liters of skim-milk will have a volume of about 3,200 cc., 250 cc. of which should be given every two hours day and night. This will provide 2,500 calories and 325 grams of protein. One patient has taken this mixture on the basis of four liters of skim-milk for a period of many weeks. If it is necessary to increase the protein still more, it can be done by reducing the amount of skim-milk powder and increasing the amount of Amigen, but such a mixture becomes relatively unpalatable, and, therefore, difficult to drink. Under these conditions, some patients should be fed this mixture by stomach tube. Generous doses of all vitamins should be added to this mixture, but do not need to be discussed at this time.

DR. ROBERT H. IVY, Philadelphia, Pa.: The essayists have presented two very excellent papers on the closing of defects. Theoretically, I would say the method used by Doctors White and Hamm is superior, probably, to that used by Doctor Gibbon, because in the former the new skin flap covers the area of the ulcer, whereas in Doctor Gibbon's method there is a line of suture over the original site of the ulcer. Practically speaking, however, the results of the two methods are equally good.

DR. FRANK L. MELENEY, New York City: I think Doctors White and Gibbon are to be congratulated on the high percentage of primary healing which they have achieved. I would be interested to know if careful bacteriologic studies were made in their cases and if they have made an analysis of their failures; particularly, to find out whether the element of infection was a factor in these failures. The organisms contaminating bedsores are usually of intestinal origin and are of low virulence and are not susceptible to penicillin. However, there are antibacterial agents available by which it is possible to minimize their activity, and by their use it might be possible to attain a still higher percentage of success.

DR. ROBERT H. KENNEDY, New York City: I have been much interested in this work. We should stop to consider that these two presentations represent dramatic methods and results which few people dreamed of as recently as three years ago. At the present time, closure of decubitus ulcers is largely taken in stride at the various Centers. The muscles are atrophied, so that skin and subcutaneous tissue can be moved quite a distance. These are long operative procedures, often three, four or five hours. I have seen nonabsorbable sutures used throughout and the results have been good. There is a striking change in the patient from the time the ulcer is closed.

He begins to have a good appetite and there is little difficulty in keeping him in positive protein balance.

CAPTAIN JAMES C. WHITE, Boston, Mass. (closing): I want to thank the discussers very much for their useful suggestions. Doctor Meleney asked about how much we had analyzed types of bacteria and the relationship of bacteria to failure. Most of the organisms were *anaerobic Streptococci, B. proteus, B. coli,* and *B. pyogenes*; but with these there were hemolytic streptococci and staphylococci. It is interesting to speculate on the effect of penicillin on the predominant type of organism. Is it really effective on organisms other than streptococci and staphylococci? We have not used streptomycin. I think the use of sulfasuxidine should be helpful. In our single failure I feel it was not due to the organism but to the poor condition of the patient. This man had tremendous loss of weight, a compound fracture of the humerus, and had had to have a cordotomy done for pain. In addition, he had had an adhesive peritonitis with partial intestinal obstruction. We closed an ulcer over the greater trochanter. There were others over the sacrum and the opposite trochanter which we were anxious to get closed because he could only lie on his right side. We tried suturing the ulcer over the other trochanter and this plastic repair broke down completely. The patient with separation of the flaps, however, had the same type of organisms, but, nevertheless, we were able to secure a satisfactory closure after secondary suture.

In dealing with some of these Marine Corps casualties who had other serious injuries and advanced malnutrition, we found intravenous amino-acids of great assistance, provided we could get an early improvement in nitrogen balance and the patient could be induced to take an adequate intake by mouth. Unfortunately the patients tolerate nasal feeding very poorly. After a few weeks intravenous feeding becomes most difficult because of thrombosis of veins and protein sensitization. One man, in whom in desperation a jejunostomy was performed, promptly developed a local area of peritonitis and obstruction. On the other hand, all our uncomplicated cases did well.

I wish we could have had advance information on the papers on burns that were read Tuesday evening. The extensive bedsores constitute a very similar problem; they all show red blood cell destruction. I think Doctor Lund's suggestion concerning the need for massive doses of vitamin C is most appropriate, particularly, as we did not want to give large amounts of fruit juice, feeling that this would increase the alkalinity of the urine. Finally, pyruvic acid paste might be helpful in getting rid of the sloughs and thereby expediting the date for plastic closure of these lesions.

DR. JOHN H. GIBBON, JR., Philadelphia, Pa. (closing): I am sorry Doctor Freeman is not here. He helped in all these cases and operated upon a number of them.

In answer to Doctor Meleney, I feel as Doctor White does. We cultured all these ulcers and found approximately the same variety of organisms that Doctor White mentioned. Our failures were not associated with any particular organism. They were due to three factors—tension, malnutrition and, in one instance, because we cut a flap with a narrow base. We preferred, as Doctor Kennedy said, to have an ulcer with clean granulations and a margin of epithelium before performing an operative closure, but we have not hesitated to operate where there were undermined pockets. You can dissect these out and not buttonhole them; after that you are working in a clean field. We used cotton and found it satisfactory; we have had no experience with catgut. The operating time, as Doctor Kennedy pointed out, can be quite long. I think we rarely exceeded two and one-half hours. The operative time is of importance because of the danger of development of pressure sores over the anterior superior spines from prolonged immobility in the prone position.

# STUDIES ON NUTRITION*

## THE EFFECT OF PREOPERATIVE FORCE-FEEDING ON SURGICAL PATIENTS

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If a large positive nitrogen balance can be induced in the average adult by an intensive feeding program lasting a few days there should be definite advantages in using this method to anticipate the nitrogen deficits of the postoperative period. Most studies of the protein requirements of surgical patients have been focused on the postoperative period when nitrogen output is high. Unfortunately, the problem of feeding certain groups of patients during this period is a difficult one often requiring special technics such as intravenous or orojejunal feedings. It seemed desirable, therefore, in those patients who could take food by mouth readily before operation to see if a large enough positive nitrogen balance could not be induced by a vigorous feeding program before operation to avoid the necessity of attempting to maintain nitrogen balance in the early postoperative period under trying and difficult circumstances.

The development of protein hydrolysates, as Co Tui[1] and his associates have pointed out, makes it possible to provide very high intakes of food nitrogen without excessive bulk.

Earlier studies at the University of Pennsylvania indicated that patients recovering from gastric and intracranial operations generally were in negative nitrogen balance during the first five days after operation and tended to regain positive balance in the second five days in most instances.[2, 3] Guided by this experience, and that of others, it was decided to study a group of patients for five days before operation on a force-feeding regimen and for five days after operation on what may be termed a *"laissez faire"* regimen. In addition to showing how much nitrogen could be accumulated with five days of forced feeding, this plan would permit an estimate of the extent to which nitrogen loss was accentuated or increased during the five days subsequent to this period as compared with patients being studied on various postoperative feeding regimens. It also seemed important to observe whether or not the patients were noticeably benefited by the preoperative force-feeding regimen. Because clinical impressions are so apt to be misleading, we sought

* The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the University of Pennsylvania.

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objective means of measuring these possible benefits. In our previous studies[4, 5] certain tests of the response of the circulation in convalescence appeared to be among the most sensitive available for our use. For that reason we selected the response of the patients' circulation to changes in position on a tilt-table equipped with a footboard.[6] In addition, the status of the circulation including the cardiac output was studied by means of a portable ballistocardiograph[7] as a means of comparing the two groups.

## PROCEDURE

At first patients were placed in the force-fed group or in the control group in rotation. As our studies progressed and as we became convinced of the benefits of the force-feeding regimen, several patients who were poor operative risks were placed in the force-feeding group in an effort to improve their care although they ordinarily would have been control patients. Thus, the treated series may have been weighted unfavorably with poor risk patients.

The patients were weighed at the start of the period of observation on a special balance used for metabolic studies. Serum protein concentration, plasma volume, cardiac output, and the response to tilting were determined at that time, and these tests were repeated just before operation and at the close of the fifth postoperative day in the force-fed group. The group serving as controls was tested before the day of operation and at the close of the fifth postoperative day. Cardiac output and the response of the circulation to tilting were determined in most patients at additional postoperative intervals.

The diets were calculated on the basis of body weight, and patients were fed a diet aimed to provide them with three times the nitrogen which we had usually found to be adequate to produce postoperative nitrogen equilibrium.[2] We attempted to feed each patient about 0.9 Gm. of nitrogen per kilogram per day and in those where 0.9 Gm. per kilogram was impossible succeeded in keeping nitrogen intake above 0.8 Gm. per kilogram per day. Three palatable meals were provided most patients each day. Additional protein was supplied as hydrolysates of casein* or lactalbumin† at intervals of several hours while patients were awake. While the feeding of protein hydrolysates in such quantity as was necessary in these studies is difficult to achieve, it was accomplished in most individuals. The objectionable taste of the interval feedings was overcome for most patients by the use of a fruit juice or chocolate milk as a vehicle or the addition of essence of peppermint as a flavoring agent. Several patients were fed by stomach tube. No serious side-effects were noted, although diarrhea occurred in a few. This symptom was controlled with camphorated tincture of opium. The abdominal distention encountered with the protein hydrolysates in postoperative jejunal feedings was not seen in this preoperative group.

* Amigen supplied by Mead, Johnson & Co.

† Lactamin (lactalbumin hydrolysate) supplied by Wyeth, Inc.

The collection of specimens and the analytical methods were the same as described in a previous paper.[2] Circulatory studies necessitating the use of the ballistocardiograph were made possible through the assistance of Dr. Robert Mayock, under the direction of Dr. Isaac Starr, and are reported in detail elsewhere.[7] The responses of patients to changes in position on the tilt-table were observed.

Eleven patients were studied in the force-fed group (Table I); there were two gastric resections, two colectomies, and seven craniotomies. Preoperatively, the interval feedings in seven patients consisted of Amigen, and in four of lactalbumin hydrolysate. Postoperatively, four patients were given intake of 0.23 Gm.N/Kg./day or over, and 30 calories per Kg./day and seven patients were followed on the usual hospital regimen of intravenous glucose and food on the fourth or fifth day.

Twelve patients were used as "controls" (Table II). The operations which they had performed consisted of five gastrectomies, two colectomies and five craniotomies. They were given diets consisting of intravenous glucose plus hospital diet, gastrostomy or intravenous protein hydrolysate postoperatively. Four patients received intakes which should have been sufficient to achieve nitrogen equilibrium. Postoperatively, the daily average nitrogen intake in the force-fed group ranged from 0.01 to 0.28 Gm./Kg. and in the control group from 0.01 to 0.52 Gm. per kilogram per day. The average intake for the postoperative period was slightly higher in the control group.

It should be emphasized that when there is reference to the "force-fed group," it refers to force feeding only in the preoperative period.

## RESULTS

*The Effect of Force-feeding on Nitrogen Balance.*—Large positive balances accumulated in every case during the force-feeding regimen. The extremes were 57.6 Gm. and 148.0 Gm. for the five-day period, and the mean was 92.2 Gm. or 18.4 Gm. per day. Thus, the daily gain was greater than the nitrogen content of one-half a pound of fresh muscle.

In 10 of the 11 patients there was a positive balance when the two periods were combined. The balances ranged from a minimum of —3.1 Gm. to a maximum of +113.3 Gm., with a mean of 55.2 Gm. for the ten days for the 11 patients. The results are tabulated in Tables I and II.

*Serum Protein Concentration.*—Preoperatively, in the force-fed group six of the 11 patients sustained a fall in serum protein concentration while five remained the same or showed an increase. However, all changes but one were minor ones, and one of the two who showed a rise in serum protein concentrations had an initial level below 7.5 Gm. per 100 ml. Postoperatively, there was little difference between the force-fed and control groups.

*Plasma Volume and Total Circulating Plasma Proteins.*—Plasma volume determinations were completed in 12 of the control patients and in eight of the force-fed group. In these cases it was possible to calculate the total circulating plasma protein. The plasma volume determinations and the total circulating plasma protein figures have been compiled in Table III.

TABLE I

TREATED GROUP

ELEVEN PATIENTS WHO RECEIVED FORCED FEEDING FOR FIVE DAYS BEFORE OPERATION

| Patient | Operation | Preoperative Feeding | Postoperative Feeding | Intake: Total Nitrogen Preop. 5 days | Intake: Total Nitrogen Postop. 5 days | Intake: Nitrogen /Kg./Day Preop. Gm. | Intake: Nitrogen /Kg./Day Postop. Gm. | Intake: Calories /Kg./Day Preop. Cc. | Intake: Calories /Kg./Day Postop. Cc. | Output: Total Nitrogen Preop. Gm. | Output: Total Nitrogen Postop. Gm. | Nitrogen Balance 10 Days Gm. | Nitrogen Balance First 5 Days Gm. | Nitrogen Balance Second 5 Days Gm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ri. | Craniotomy | Amigen + hospital | Hospital | 274.3 | 36.3 | 0.82 | 0.11 | 45 | 21 | 126.3 | 92.3 | + 92.0 | +148.0 | —56.0 |
| Fe. | Craniotomy | Lactalbumin + hospital | Hospital | 302.8 | 26.7 | 0.89 | 0.08 | 49 | 15 | 168.6 | 95.5 | + 65.4 | +134.2 | — 68.8 |
| Sm. | Gastric resection | Amigen + hospital | I.V. glucose + hospital | 275.5 | 20.7 | 0.89 | 0.07 | 44 | 15 | 165.4 | 49.7 | + 81.1 | +110.1 | —29.0 |
| Ho. | Craniectomy | Amigen + hospital | Gastrostomy + hospital | 220.2 | 41.2 | 0.77 | 0.14 | 45 | 21 | 152.1 | 69.4 | + 39.9 | + 68.1 | —28.2 |
| Wa. | Rankin resection | Amigen + hospital | I.V. glucose | 193.6 | 5.8 | 0.70 | 0.02 | 50 | 10 | 136.0 | 66.5 | — 3.1 | + 57.6 | —60.7 |
| Do. | Rankin resection | Lactalbumin + hospital | I.V. glucose | 244.6 | 7.8 | 0.80 | 0.02 | 39 | 6 | 163.7 | 68.8 | + 19.9 | + 80.9 | — 61.0 |
| Pa. | Gastric resection | Lactalbumin + hospital | I.V. glucose | 260.2 | 2.6 | 0.83 | 0.01 | 38 | 8 | 146.7 | 47.5 | + 68.6 | +113.5 | —44.9 |
| Th. | Craniotomy | Amigen + hospital | Hospital | 271.7 | 71.4 | 0.86 | 0.23 | 42 | 26 | 200.3 | 96.8 | + 46.0 | + 71.4 | —25.4 |
| Wi. | Craniotomy | Amigen + hospital | Hospital | 282.2 | 86.0 | 0.83 | 0.25 | 46 | 26 | 195.3 | 98.2 | + 74.7 | + 86.9 | —12.2 |
| Bo. | Craniotomy | Amigen + hospital | Hospital | 319.8 | 100.7 | 0.89 | 0.28 | 50 | 27 | 181.7 | 125.5 | +113.3 | +138.1 | —24.8 |
| Sc. | Craniotomy | Lactalbumin + hospital | Lactalbumin + dextri-maltose | 210.0 | 85.3 | 0.78 | 0.25 | 49 | 26 | 111.5 | 119.0 | + 64.8 | + 98.5 | —33.7 |

Only one of the eight force-fed patients had more circulating plasma protein at the end of the ten-day study than at the beginning of the feeding regimen. It is of interest that this patient was the only individual among the eight whose initial serum protein concentration was below 6.0 Gm. per 100 ml. If, however, one considers only the period from operation to the end of the first five postoperative days one finds that three of the eight patients had an increase in total circulating plasma protein as compared with five of 12 of the control patients who were studied only during this period.

The changes in the serum protein concentration and total circulating serum protein in the force feeding period are contrary to what one would

TABLE II

TWELVE PATIENTS WHOSE NUTRITION IN THE PREOPERATIVE PERIOD WAS NOT STUDIED

| | | | Intake | | | Output | |
|---|---|---|---|---|---|---|---|
| Patient | Operation | Feeding | Total Nitrogen 5 Days | Nitrogen /Kg./Day | Calories /Kg./Day | Total Nitrogen 5 Days | Nitrogen Balance |
| | | | Gm. | Gm. | | Gm. | Gm. |
| McG. | Gastric resection | I.V. glucose | 1.8 | 0.01 | 9 | 57.3 | —55.5 |
| Ka. | Abdomino-perineal resection | I.V. glucose | 6.5 | 0.02 | 4 | 40.7 | —34.2 |
| Fa. | Gastric resection | I.V. glucose + hospital | 8.0 | 0.03 | 9 | 54.3 | —46.3 |
| Ca. | Gastric resection | I.V. glucose + hospital | 9.7 | 0.03 | 9 | 40.0 | —30.3 |
| Sm. | Craniotomy | Hospital | 49.6 | 0.12 | 17 | 72.9 | —23.3 |
| Fe. | Craniotomy | I.V. glucose + hospital | 32.0 | 0.13 | 12 | 92.5 | —60.5 |
| Wi. | Craniotomy | Hospital | 34.3 | 0.17 | 29 | 35.4 | — 1.1 |
| Bu. | Craniotomy | Gastrostomy | 77.9 | 0.18 | 19 | 125.9 | —48.0 |
| Le. | Craniotomy | Gastrostomy | 60.8 | 0.22 | 20 | 133.3 | —72.5 |
| Fat. | Gastro-enterostomy | Casein Aminosol + gelatin | 62.4 | 0.25 | 28 | 67.5 | — 5.1 |
| Mi. | Colectomy | Casein Aminosol + gelatin | 86.0 | 0.29 | 29 | 98.0 | —12.0* |
| Cr. | Gastric resection | Fibrin Aminosol + glucose | 117.7 | 0.52 | 33 | 101.4 | +16.3 |

* Period of study on this patient is for the first five postoperative days. All others are for operative day and four postoperative days.

expect. Both before and after operation the differences are small and the mean figures for protein concentration are within normal limits, so that one would not be justified in drawing either positive or negative conclusions. They do suggest that patients with normal serum protein levels do not store appreciable amounts of protein as plasma protein on the force feeding regimen employed.

*Response to Tilting.*—The reaction of pulse and blood pressure to change in position from the horizontal to 15 degrees from the vertical on a tilt-table was measured in eight of the force-fed and nine of the control patients. As our experience with this test increased, it seemed less sensitive than we had thought at the outset of this work. Many variables enter into the interpretation of the results, and only a brief summary is reported here.

Both groups acted essentially like normal individuals before operation when subjected to changes in position on the tilt-table. The most obvious response to tilting was loss of consciousness when tilted from the horizontal to the vertical position on the fifth postoperative day. Of the eight patients in the force-

TABLE III

PLASMA VOLUME AND TOTAL CIRCULATING PLASMA PROTEIN DATA

| | Controls | | | | | | Force-Fed | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Serum Protein Concentration | | Plasma Volume | | Total Circulating Plasma Protein | | | Serum Protein Concentration | | | Plasma Volume | | | Total Circulating Plasma Protein | | |
| Patient | Preop. Gm. % | Postop. Gm. % | Preop. Cc. | Postop. Cc. | Preop. Gm. | Postop. Gm. | Patient | Preop. Gm. % | Oper. Gm. % | Postop. Gm. % | Preop. Cc. | Oper. Cc. | Postop. Cc. | Preop. Gm. | Oper. Gm. | Postop. Gm. |
| Fa. | 7.8 | 7.5 | 3,356 | 2,712 | 262 | 203 | Ri. | 7.3 | 7.0 | 7.2 | — | — | — | — | — | — |
| Ca. | 6.1 | 6.4 | 3,132 | 3,385 | 191 | 217 | Sm. E. | 7.6 | 7.7 | 7.5 | 2,227 | 2,242 | 2,000 | 169 | 173 | 150 |
| Ka. | 5.4 | 5.6 | 2,100 | 2,445 | 113 | 137 | Wa. | 6.8 | 6.9 | 5.5 | 2,500 | 2,000 | 2,702 | 170 | 138 | 149 |
| McG. | 7.2 | 6.5 | 2,940 | 5,555 | 212 | 361 | Do. | 6.8 | 6.7 | 5.8 | 3,436 | 3,636 | 2,570 | 234 | 244 | 149 |
| Sm. | 7.4 | 7.1 | 4,273 | 2,762 | 316 | 196 | Pa. | 7.1 | 7.0 | 6.5 | 2,898 | 3,048 | 3,012 | 206 | 213 | 196 |
| Bu. | 7.6 | 6.7 | 2,793 | 2,976 | 212 | 199 | Fel. | 5.8 | 7.4 | 6.9 | 2,040* | 2,525 | 2,347 | 118 | 187 | 162 |
| Wi. | 7.2 | 7.5 | 1,519 | 1,492 | 109 | 112 | Th. | 7.2 | 7.8 | 7.0 | — | — | — | | | |
| Le. | 5.6 | 6.6 | 3,105 | 3,067 | 174 | 202 | Wi.W. | 8.0 | 7.6 | 7.5 | 3,080 | 2,570 | 2,840 | 246 | 195 | 213 |
| Fat. | 6.4 | 6.3 | 4,201 | 3,921 | 269 | 247 | Bo. | 6.1 | 5.0 | 6.7 | 3,773* | 4,032 | 3,472 | 230 | 202 | 233 |
| Mi. | 6.6 | 6.2 | 3,389 | 3,076 | 224 | 191 | Ho. | 7.5 | 6.8 | 7.1 | — | — | — | | | |
| Fe. | 7.7 | 6.3 | 1,901 | 2,159 | 146 | 136 | Sc. | 7.3 | 7.7 | 7.4 | 2,762 | 2,386 | 2,688 | 202 | 184 | 199 |
| Ca | 6.6 | 6.1 | 2,784 | 2,688 | 184 | 164 | | | | | | | | | | |

* Blood protein concentration and blood volume not done on same day.

fed group, one fainted and one who was about to faint was returned to the horizontal position because of the intensity of his subjective complaint. In the control group three of nine patients had continuous intravenous fluids up to the time of the test and cannot be considered with the rest. Of the six remaining, however, three fainted.

The average drop in systolic blood pressure was almost identical in the two groups. Pulse rate elevations, however, were dissimilar. In the force-fed group the average rise in pulse was 22 beats per minute while in the control group the rise was 32 beats per minute.

If one uses paired experiments to bring out differences in the response of patients treated with varied regimens, some benefits of the force-feeding program become more evident. In selecting pairs with regard to operative procedure and age-group, three general surgical and three neurosurgical pairs can be matched. Three of the paired controls lost consciousness with change of position to the vertical while none of the force-fed partners fainted. Other changes, such as absent radial pulses, excessive sweating, and dizziness in the vertical position were much more evident in the control than in the force-fed group. A comparison of two patients, one prefed and one control, who had gastric resections for peptic ulcer, is illustrated in Figure 1.

*Ballistocardiographic Tracings.*—The ballistocardiographic records from these patients were included in a larger group for analysis. The question of whether patients whose stores of nitrogen were maintained by special methods of feeding before or after operation were in better condition than those who went into more negative nitrogen balance has been the subject of another report under the general title of "Convalescence from Surgical Procedures."[7] It was the impression of the surgeons that those given extra feedings were benefited. Mayock, Koop, Riegel, Kough and Starr[7] believe they have confirmed this. Ballistocardiographic abnormalties occurred much more frequently after operation in all the patients whose nitrogen balances were negative. Inasmuch as both age and type of operative procedure are probably factors in causing these abnormalities, the patients were again paired with reference to operation first and age second. From this type of analysis it was apparent that the individual in better metabolic condition developed fewer ballistic abnormalities after operation than did the patient with whom he was paired. The results were not significant statistically, but, as the authors state in their detailed report, the changes were 92 out of 100 that a negative nitrogen balance is associated with the development of ballistocardiographic abnormalities after operation.

*Clinical Course.*—In spite of the fact that clinical impressions can be misleading, there was enough evidence of a better response in the force-fed group to be convincing to the observer. The differences were most marked in comparing the neurosurgical patients in the two groups. Those who had been force-fed needed ventricular taps for increased intracranial pressure less frequently than did controls. They were ambulatory sooner and showed less postoperative facial edema. Results were more difficult to measure in the general surgical group, but all the force-fed patients had benign postoperative

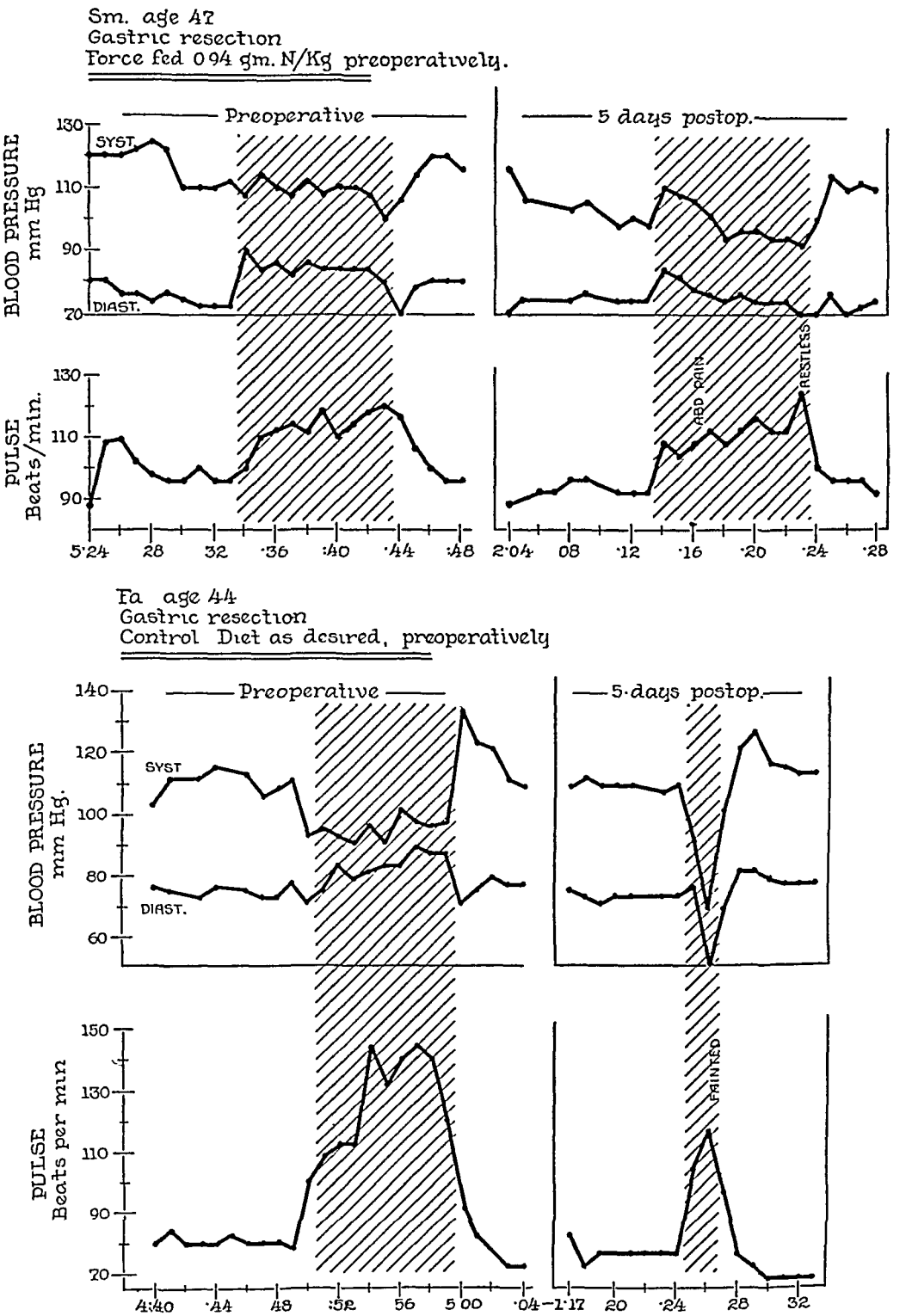



FIG. 1.—The response to tilting in a force-fed patient compared with his control.

courses in spite of the fact that several of them had extensive unavoidably traumatic and time-consuming procedures.

DISCUSSION.—It should be stated that the control series was not studied for five days before operation, and for this reason these patients are not controls in the strict sense of the word. It is a reasonable assumption, however, that these patients had either maintained themselves in equilibrium or were in negative balance during the week before operation. There is also a possible question whether or not the extra nitrogen accumulated in the body during the force-feeding period is as readily available during the postoperative period as food nitrogen absorbed from the alimentary tract from day to day. At present we have no reason to doubt that it is as available.

One of the chief objectives of our studies in convalescence and nutrition has been to ascertain if the patients in nitrogen equilibrium responded better to operation than those who were in negative nitrogen balance. It was our impression that a group of patients force-fed preoperatively did respond better after major surgical procedures than did those whose nutrition preoperatively had not been controlled. Some data presented here, and in the detailed reports dealing with circulation and nutrition, support that clinical impression.

Although the nitrogen balances in the two groups for the postoperative periods alone were somewhat less negative in the control group, the group force fed preoperatively were able to draw upon an accumulated store of nitrogen from the five preoperative days and thereby remain in positive cumulative nitrogen balance when the five preoperative and the five postoperative days were considered together.

The response of the circulation to changes in position on a tilt-table, while not as clear-cut in demonstrating the benefits of positive balance because of the number of variables involved, did indicate a higher degree of fitness in the force-fed group.

In those patients who can be fed by mouth, or by tube, it seems logical to spend five days before operation with a vigorous nutritional program at a time when very high nitrogen and caloric intakes are possible and when the patient is in comparative comfort rather than to spend the same number of days postoperatively in attempting to achieve nitrogen equilibrium under trying and difficult circumstances. It was our impression that patients force-fed preoperatively were in better condition on the fifth postoperative day than were patients operated upon without special preparation.

## CONCLUSIONS

Eleven patients undergoing extensive abdominal or neurosurgical operations were prepared for five days before operation by diets providing them with 0.8 to 0.9 Gm. of nitrogen per kilogram per day. This intake was made possible by supplements of hydrolyzed protein given by tube when necessary. This regimen resulted in a large retention of nitrogen in each individual, averaging 92.2 Gm. per patient for the five-day preoperative period. Except in one instance the positive balance in each case was more than enough to compensate for the negative balance occurring in the five days after operation.

The mean balance per patient for the ten-day period, beginning five days before operation, was +55.2 Gm. of nitrogen.

The retained nitrogen was not stored in general as plasma protein. In fact, the mean total circulating plasma protein decreased moderately in the eight patients in which this was measured, except in the case of the single patient whose initial serum protein level was below 6.0 Gm. per 100 ml.

A group of 12 similar patients who received no special diet before operation were studied for five days postoperatively for comparison. Two tests of physical fitness, the ballistocardiograph and the tilt-table test, supported the clinical impression that the patients maintained in better nutritional condition were in better physical condition as well.

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DISCUSSION.—DR. CHARLES C. LUND, Boston, Mass.: Doctor Rhoads, and his collaborators, should be congratulated on carrying out this very difficult type of work. Metabolism studies are time-consuming and difficult to plan, and difficult to carry out in a large number of cases. These results I would interpret in one way slightly different from the way he has done so. He spoke of trying to put in extra amounts of nitrogen in order to accumulate a nitrogen store in the body. I am wondering if we should not think in terms of optimums, and I am wondering if his accumulated store is not merely repair of an unrecognized deficiency. In spite of the fact that these patients had fairly normal protein levels in the blood and tissue, maybe our standards of what is normal are not standards of what could be, or should be, considered optimum.

That brings in the whole problem in differentiation of chemical efficiency of the highly trained athlete, the highly trained soldier, compared with the average individual. The highly trained soldier, the highly trained athlete can run four miles, can keep going for a long time, and can stand surgery in a way that the average patient cannot. I have wondered for a long time whether the fact that the great Doctor McDowell did the first successful oophorotomy, rather than the great surgeons of the early 19th century in Boston or Philadelphia or New York, was not due to the fact that he had patients who were so much tougher than the ladies of the east, and he was able to get away with operations that could not be done in the east.

I think further study along the line of nutrition may show that we must concentrate on optimum supply, and even in a short period we may be able to do things we have not been able to do in the past.

DR. JONATHAN E. RHOADS, Philadelphia, Pa. (closing): I think Doctor Lund's point is very well taken. We have serum protein measurements and plasma volume measurements in most cases which indicate that, with one or two exceptions, these patients were not grossly hypoproteinemic, but it is probable that they were not in optimum condition. However, I think they fairly represent the ordinary patient admitted for surgery whom one would not consider as having any gross nutritional deficiency.

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